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ITR-1319

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OPERATION REDWING -- ~~PRELIMINARY REPORT~~

PROJECT 2.65

DECEMBER 1956

LAND FALLOUT STUDIES

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SUMMARY OF SHOT DATA, OPERATION REDWING

Shot Name (Unclassified)	Date (PPG)	Time (Approximate)	Location	Type	H&N Coordinates (Actual Ground Zero)	Geographic ° ' "
Lacrosse	5 May	0629	Eniwetok Yvonne	Surface Land	124515 E 106885 N	11 33 29 162 21 18
Cherokee	21 May	0551	Bikini Off Charlie	Air Drop (4320±150 ft) Over Water	96200 ± 100 E 185100 ± 500 N	11 43 50 165 19 46
Zuni	28 May	0556	Bikini Tare	Surface Land Water	110909 E 100154 N	11 29 48 165 22 09
Yuma	28 May	0756	Eniwetok Sally	200-ft Tower	112155 E 130604 N	11 37 24 162 19 13
Erie	31 May	0615	Eniwetok Yvonne	300-ft Tower	127930 E 102060 N	11 32 41 162 21 52
Seminole	6 June	1255	Eniwetok Irene	Surface Land[a]	75237 E 149897 N	11 40 35 162 13 02
Flathead	12 June	0626	Bikini Off Dog	Barge Water	116768 E 164094 N	11 40 22 165 23 13
Blackfoot	12 June	0626	Eniwetok Yvonne	200-ft Tower	126080 E 104435 N	11 33 04 162 21 33
Kickapoo	14 June	1126	Eniwetok Sally	300-ft Tower	114018 E 132295 N	11 37 41 162 19 32
Osage	16 June	1314	Eniwetok Yvonne	Air Drop (680±35 ft) Over Land	126647 ± 50 E 102851 ± 50 N	11 32 48 162 21 39
Inca	22 June	0956	Eniwetok Pearl	200-ft Tower	105300 E 133540 N	11 37 53 162 18 04
Dakota	26 June	0606	Bikini Off Dog	Barge Water	116767 E 164097 N	11 40 22 165 23 13
Mohawk	3 July	0606	Eniwetok Ruby	300-ft Tower	109737 E 132165 N	11 37 39 162 18 49
Apache	9 July	0606	Eniwetok Flora	Barge Water	69227 E 148063 N	11 40 17 162 12 01
Navajo	11 July	0556	Bikini Off Dog	Barge Water	116816 E 160604 N	11 39 48 165 23 14
Tewa	21 July	0546	Bikini Charlie-Dog Reef	Barge Water	99776 E 164476 N	11 40 26 165 20 22
Huron	22 July	0616	Eniwetok Flora	Barge Water	70015 E 148304 N	11 40 19 162 12 09

[a]See ITR-1344 for further details.

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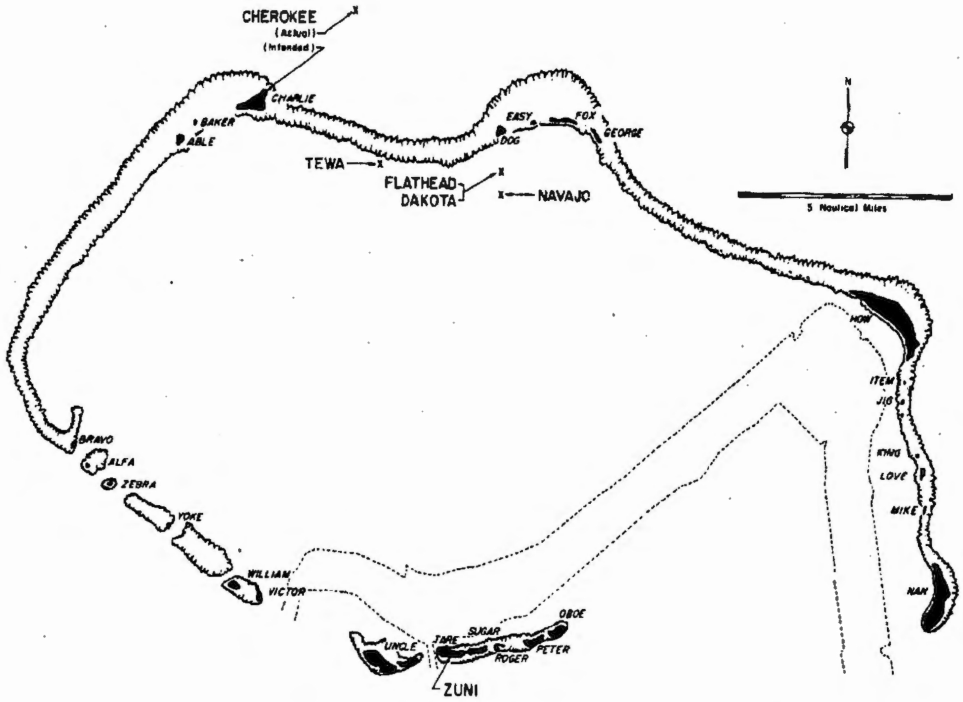

Airukiiji	Oboe	Bokoaetokutoku	Alfa	Eniirikku	Uncle	Rochikarai	Love
Airokiraru	Peter	Bokobyaadaa	Able	Eninman	Tare	Romurikku	Fox
Aomoen	George	Bokonejien	Baker	Enyu	Nan	Rukoji	Victor
Arriikan	Yoke	Bokonfuaaku	Rem	Ionchebi	Mike	Uorikku	Easy
Bigiren	Roger	Bokororyuru	Bravo	Namu	Charley	Yomyaran	Jig
Bikini	How	Chieerete	William	Ourukaen	Zebra	Yurochi	Dog
		Eniairo	King	Reere	Sugar		

Bikini Atoll. Locations of test detonations during Operation REDWING are indicated by large lettering and arrows. Native island names with corresponding military identifiers are given in the tabulation.

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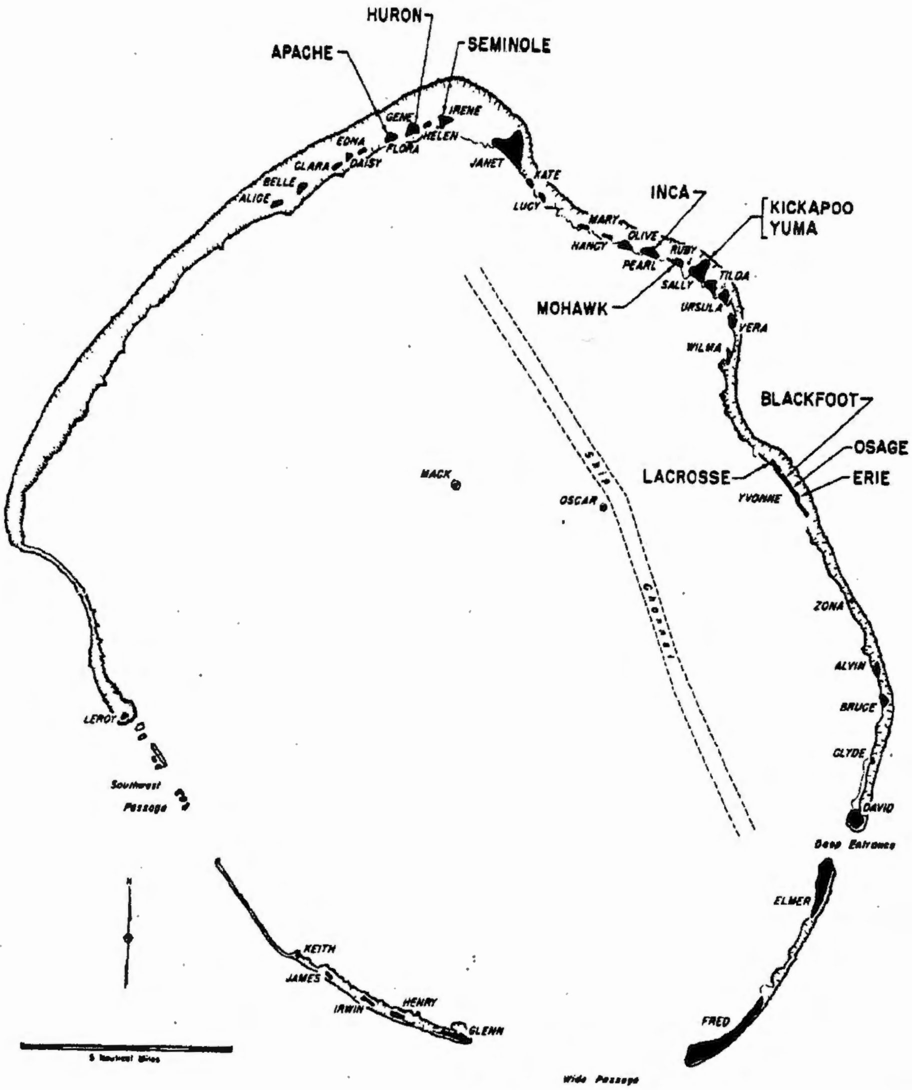

Aaraanbiru	Vera	Chinieero	Alvin	Igurin	Glenn	Ribaion	James
Aitsu	Olive	Chinimi	Clyde	Japtan	David	Rigili	Leroy
Aniyaanii	Bruce	Cochita	Daisy	Kirinian	Lucy	Rojoa	Ursula
Aomon	Sally	Coral Heads	Mack, Oscar	"M"	Zona	Ruchi	Clara
Bijiri	Tilda	Eberiru	Ruby	Mui	Henry	Rujoru	Pearl
Bogairikk	Helen	Elugelab	Flora	Muzin	Kate	Runit	Yvonne
Bogallua	Alice	Engebi	Janet	Parry	Elmer	Sandildefonso	Edna
Bogombogo	Belle	Eniwetok	Fred	Piiraai	Wilma	Teiteiripucchi	Gene
Bogon	Irene	Giriinien	Keith	Pokon	Irwin	Yeiri	Nancy
Bokonaarappu	Mary						

Eniwetok Atoll. Locations of test detonations during Operation REDWING are indicated by large lettering and arrows. Native island names with corresponding military identifiers are given in the tabulation.

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ABSTRACT

Project 2.65 studied the fallout resulting from three land-surface shots, two water-surface shots, and one air burst to: (1) obtain fallout samples and perform radiophysical and radiochemical measurements on the samples; (2) prepare dose-rate contours in the immediate area of the atoll from information gathered by this project, other projects, and Rad-Safe; and (3) evaluate the role of base surge in the transport of radioactive material.

Time incremental and gross fallout samples were collected on islands of Bikini Atoll, on a barge in Bikini Lagoon, and on three ships in the downwind fallout area following Cherokee, an air burst; Zuni and Tewa, land-surface shots; and Navajo and Flathead, water-surface shots. Gross fallout samples were collected on islands of Eniwetok Atoll following Lacrosse, a land-surface shot.

Contamination levels existing at specific points on the islands were measured following Shots Lacrosse, Zuni, Flathead, Mohawk, Navajo, and Tewa by the lowering of a probe from a helicopter to a distance of 3 feet from the ground surface.

Base-surge detectors, consisting basically of a photovoltaic cell upon which a light beam was focused, were installed at a few close-in stations for Zuni, Flathead, Navajo and Tewa.

No fallout over the atoll was observed following the Cherokee air drop. All fallout collectors were monitored, as was a dirt sample from the intended ground zero, but no activity was detected.

Preliminary analysis of the fallout samples from the other events provided information on the gamma dose rate decay; the beta decay rate; the weight, activity, radiochemical composition, time of arrival, rate, and duration of fallout; and on the nature of individual fallout particles. There was good agreement between early field and laboratory dose rate decay slopes. The decay exponent for Lacrosse was about -1.35; for all other events, the decay exponent fluctuated around -1.0.

The fallout resulting from the water-surface shots differed in nature from that of the land-surface shots. In the case of Flathead, most of the activity was associated with a slurry, or mud, which contained $CaCO_3$ particles, Fe_2O_3 particles, and NaCl crystals. In the case of Navajo, most of the activity was associated with liquid fallout and with a slurry of NaCl crystals. The Lacrosse and Zuni fallout, on the other hand, consisted chiefly of particles derived from coral. In the samples examined for Lacrosse and Zuni, a large majority of the particles making up the fallout were radioactive throughout their volume.

The capture-to-fission ratios varied with type of fallout and distance from ground zero. Furthermore, the cloud samples from Zuni and

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Lacrosse had lower ratios than the solid fallout. The activity per unit weight of fallout resulting from land-surface bursts was higher at distant stations than at relatively close-in stations.

(b) (3)

An aerial survey instrument provided a practical means of determining precise contamination levels at surface locations in a high-radiation field. The maximum radiation intensities measured on the ground near the Lacrosse and Mohawk craters were higher than those reported after any previous nuclear detonation. Consistent H+1 hour dose rates from 10,000 to 13,000 r/hr were obtained in the neighborhood of the Mohawk crater.

No results are available at this time on the evaluation of the role of base surge in the transport of radioactive material.

FOREWORD

This report presents the results of one of the 48 projects participating in the Military Effects Program of Operation REDWING, which included 17 test detonations.

For readers interested in other pertinent test information, reference is made to ITR-1344, Summary Report of the Commander, Task Unit 3. This summary report includes the following information of general interest: (1) an overall description of each detonation, including yield, height of burst, ground zero location, time of detonation, and ambient atmospheric conditions at detonation; (2) a discussion of all project results; (3) a summary of each project, including objectives and results; and (4) a complete listing of all reports covering the Military Effects Program.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The work performed during Operation REDWING by Project 2.65 was a logical extension of fallout studies conducted during previous nuclear tests. The project was responsible for land fallout studies, one phase of an extensive program on fallout. The studies should help to increase the knowledge of weapon effects and provide measurements of value in the construction and evaluation of fallout-prediction models.

The objectives of Project 2.65 were to: (1) obtain fallout samples on land and perform radiophysical and radiochemical measurements on the samples; (2) prepare dose-rate contours in the immediate area of the atoll from information gathered by this project, other projects, and Rad-Safe; and (3) evaluate the role of the base surge in the transport of radioactive material.

1.2 MILITARY SIGNIFICANCE

When a nuclear explosion occurs on or near the surface of land or water, radioactive debris is later deposited over the surface as fallout. This contamination constitutes a radiation hazard which must be considered in both offensive and defensive planning. Many offensive and defensive procedures pertinent to the use of nuclear weapons depend upon accurate definition of the extent and location of the radioactive area. Some of the present work was designed to determine the residual-radiation patterns resulting in the immediate area of the atoll so that, in combination with other projects, complete residual-radiation patterns could be developed.

It is also important to be able to predict the fallout, including dose-rate contours, time of arrival, rate of arrival, duration, and rate of decay. For this purpose several agencies have proposed prediction models (Reference 1). In order to evaluate these models, the effects listed above must be documented during tests of nuclear devices. The various fallout-prediction models are based on different assumptions regarding the nature of the bomb cloud. These assumptions are necessitated by the lack of basic input data; e.g., particle-size distribution, distribution of activity with particle size, and spatial distribution in the cloud. Some of these data can be measured directly on fallout samples, but others must be derived from fallout measurements in conjunction with

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meteorological data.

The information available on the contamination levels within the area of complete destruction for contaminating-type bursts of nuclear devices is sketchy. This is particularly true for the first few hours after burst. According to the "Capabilities of Atomic Weapons" (Reference 2), the maximum residual radiation intensities observed on the ground at a reference time of H+1 hour have been more than 3,000 r/hr and less than 10,000 r/hr for surface bursts of nuclear weapons. The information available from reports on previous atomic weapon tests indicates that the apparent maximum dose rate varies only from 6,000 r/hr to 8,000 r/hr at 1 hour, despite a ten-thousandfold variation in yield. In most instances these H+1 hour maximum dose-rate values have been calculated from readings obtained at a much later time and have not taken into account the contribution of any short-lived induced activities. These figures need confirmation in order to estimate the period of denial for areas where early occupancy for short time intervals is necessary and to determine the effect upon continued occupancy or exit from underground fortifications.

Participation of this project in the test of an air-burst weapon in the megaton range was included because of the military importance of determining whether such a burst results in significant fallout contamination.

1.3 BACKGROUND

1.3.1 Dose-Rate Contours. Documentation of fallout from surface and subsurface nuclear detonations has been conducted at previous test operations. The phenomenon was first observed following the TRINITY test at Alamagordo, New Mexico, in 1945 (Reference 3). Since that time, through Operations JANGLE, IVY, CASTLE, and TEAPOT, it has become well established that the residual gamma-radiation hazard resulting from fallout must be considered seriously as a problem of military significance for all types of detonations, except where the fireball does not touch the surface of the earth. Prior to Operation REDWING, an air burst of a multimegaton weapon had not been conducted, and the amount of contamination resulting from such a detonation needed to be established.

Fallout was first fully documented during JANGLE, although limited data were obtained during CROSSROADS and GREENHOUSE. After CROSSROADS, the residual gamma radiation from a nuclear detonation was first reported as theoretical dose-rate contours (Reference 3). The first comprehensive study of fallout forecasting was made during GREENHOUSE (Reference 4). The latter study revealed correlation of the residual contamination from the Dog and Easy tower shots with the wind profiles.

In the JANGLE fallout studies, data were obtained to a distance of several miles from ground zero (Reference 5). Contamination patterns for both the surface shot (1.2 KT) and the underground shot (1.2 KT, at a depth of 17 feet) were reported as dose-rate contours (Reference 6).

The radioactive fallout from tower shots during Operations TUMBLER-SNAPPER and UPSHOT-KNOTHOLE was plotted as dose-rate contours by use of the data from the radiological monitoring logs of the Rad-Safe ground and air surveys (Reference 7).

The distribution, time of arrival, and early rate of fallout were

[redacted]

measured during Operations IVY (Reference 8) and CASTLE (Reference 9). The residual-radiation hazard resulting from the fallout of radioactive particles generated in the surface detonation of very high yield nuclear weapons was demonstrated during CASTLE (Reference 10). The fallout involved vast areas extending well beyond those areas affected by damaging blast and thermal effects. Radiation levels of military significance were found to exist at downwind distances greater than 180 miles.

During Operation TEAPOT, measurements of ground and aerial radiation intensity following Shot 7 (1.2 KT, at a depth of 67 feet) were used to arrive at closed contour lines for H+1 hour dose rates of 100 mr/hr or higher (Reference 11). This test marked the first use of a newly developed aerial-survey instrument to give rapid and accurate determinations of dose rates at the 3-foot level. The aerial-survey instrument (Reference 12) consisted of an external probe operated at the end of a special 500-foot cable, which was lowered from a helicopter. This instrument was subsequently improved and used during this operation to give rapid and accurate determinations of dose rates above land stations where excessive contamination would prohibit surface entry.

During Operation TEAPOT, a preliminary evaluation was made of a technique for calibrating a laboratory gamma-detecting instrument to obtain the infinite field dose rate from a small sample. The results were promising, but a need was indicated for some further work.

1.3.2 Particle Characteristics. Extensive measurements of the size distribution and activity of fallout particles were made during previous tests of nuclear devices, but the definitive input data required for fallout-prediction models were not obtained.

As a theoretical approach to the problem of deriving basic input data, attention has been given to the mechanism of particle formation. Radiochemical analyses of the solid fallout during JANGLE (Reference 13) and CASTLE (Reference 14) demonstrated the dependence of radiochemical composition on particle size and the fact that different radionuclides were associated with the particles in different ways. These phenomena are often referred to as fractionation. Interpretation of these results, along with the microscopic examination of particles, has led to preliminary ideas about particle formation. Additional data were needed to check the CASTLE results and to further develop these ideas.

Radiochemical analyses performed on the fallout from Shot 7 of Operation TEAPOT indicated a constant Sr^{90}/Ba^{140} ratio (Reference 15). If this ratio is reproducible for nuclear devices which differ in yield and conditions of detonation, the Sr^{90} level in bomb debris could be rapidly estimated by Ba^{140} analysis. This procedure would be advantageous because the concentration of Ba^{140} is much easier to determine than of Sr^{90}. Operation REDWING provided an opportunity to test the reproducibility of the ratio.

1.3.3 Base Surge. When the column from a subsurface detonation subsides, it may produce a dense cloud, called the base surge, which flows radially along the surface with a high initial velocity. As it decreases in density and velocity, the base surge gradually rises from the surface to form a low cloud.

The base-surge phenomenon was first observed during Shot Baker of

[redacted]

Operation CROSSROADS (Reference 3). Since it was an unexpected occurrence, little in the way of base-surge data was obtained, and conflicting conclusions were drawn concerning the role of the base surge in carrying activity. Documentation of the base surge was first carried out systematically during the JANGLE underground shot, but only a limited amount of information was obtained. Basic physical effects data were obtained, but the question of base-surge activity was not resolved. An analysis of the time of arrival of activity, radiochemical data, photography, and all other available information from the underground shot during TEAPOT indicated that the base surge was the primary carrier of activity in the upwind and crosswind directions (Reference 4). It is unknown whether the high-yield surface detonations of Operations IVY and CASTLE produced a base surge. Attempts to sample base surge during Operation CASTLE were thwarted by the destruction of the raft measuring stations by heavy seas.

The ideas on particle formation developed from the results of Operation CASTLE, in conjunction with the accepted model of base surge formation, indicated that a radioactive base surge would be deficient in gaseous precursor nuclides, such as Sr^{89} and Ba^{140}. (Sr^{89} and Ba^{140} have 2.6 m Kr^{89} and 16 s Xe^{140} parents respectively.) Because of the chemical inertness of these gases, they cannot become appreciably associated with particles until some decay has taken place. Hence, material which leaves the cloud very early should be deficient in these nuclides (Reference 16). The TEAPOT results appear to confirm this theory, but the unusual nature of the test makes it inadvisable to extrapolate the results to detonations at a lesser scaled depth.

1.3.4 Salted Weapons. Proposals have been made recently to salt thermonuclear weapons by incorporating into them elements whose neutron-capture products would control the radiological hazard of fallout (Reference 17). Small amounts of several candidate elements were placed in the Navajo device during REDWING in order to evaluate the feasibility of salting. Some of these elements were incidentally included in the Zuni device, but in less favorable locations. Radiochemical analyses for the reaction products were necessary for the estimation of the efficiency of the process.

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CHAPTER 2

PROCEDURES

2.1 EXPERIMENT DESIGN

Project 2.65 was designed to determine the close-in contamination levels resulting from several of the shots of the REDWING series and to collect information regarding the nature of the fallout material, time of arrival, rate and duration of fallout, and the formation and significance of base surge for high yield surface bursts.

Full participation of this project in weapon tests held at both Bikini and Eniwetok Atolls was impractical because of overlapping shot schedules and the consequent necessity for a duplication of field equipment and personnel on the two atolls. Because of greater interest within the Department of Defense in the results of the detonations of high-yield weapons, Project 2.65 emphasized participation in the Bikini shots but did also participate, on a limited basis, in two shots at Eniwetok. Project participation was thus limited to seven shots: Cherokee, Zuni, Flathead, Navajo, and Tewa (at Bikini), with yields ranging from approximately 1/3 to 5 MT; and Lacrosse and Mohawk (at Eniwetok), with yields of approximately 38 KT and 350 KT, respectively.

Contamination levels existing at specified points were measured on the day of the shot by a probe lowered from a helicopter to within 3 feet of the ground surface, and at later times, by ground survey parties. In addition, Signal Corps recording dose-rate meters were installed at or near Project 2.65 stations through coordination with Project 2.2.

Sample collection on Bikini Atoll was accomplished by using three types of collectors: (1) the intermittent fallout collector (IFC), which collects 22 time-incremental samples; (2) the gross fallout collector (GFC), which collects samples for a period of 11 hours after shot; and (3) the tape fallout monitor (TFM), which collects samples on a sticky tape which moves periodically to expose new collection surfaces. The sampling tape monitor was developed to corroborate the time-of-arrival data of the intermittent fallout collector and to establish the time of cessation of fallout. These instruments were actuated by an Edgerton, Germeshausen, and Grier, Inc. (EG&G) blue box, which responds to the light from the bomb.

The base-surge detector consists basically of a photovoltaic cell upon which a light beam is focused. The passage of the base surge decreases the light intensity reaching the photovoltaic cell. A Brown recorder connected to the cell produces a permanent record of changes in the light intensity. This instrument indicates the time of passage and relative density of the base surge, if it exists at the stations selected.

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An H-1 minute wire signal was used to actuate the base-surge indicator.

A description of all field instruments used by this project is included in Appendix A.

The basic station layout for Bikini Atoll is shown in Figure 2.1. This layout was planned to provide for maximum coverage of the islands with a minimum of equipment movement from shot to shot. The station on Site Charlie was not instrumented until after Shot Cherokee, the Uncle station was not used for Zuni, and the Dog station was removed prior to Navajo. For Tewa, the YFNB-29 was moved to the western portion of the lagoon.

Instrumentation of the stations for each of the first three Bikini events is shown in Table 2.1 and, for Navajo and Tewa, in Tables 2.2 and 2.3. In general, where two intermittent fallout collectors were placed

TABLE 2.1 INSTRUMENTATION OF PROJECT 2.65 STATIONS AT BIKINI FOR CHEROKEE, ZUNI, AND FLATHEAD

Location	Intermittent Fallout Collectors (IFC)	Gross Fallout Collectors (GFC)	Base Surge Detector (BSD)	Tape Fallout Monitors (TFM)	Distant Fallout Collectors (DFC)
YFNB-29	1	1	0	0	0
Charlie	2[a]	1[a]	0	1[a, c]	0
Dog	1	1[b]	0	0	0
Fox	1	1	1[a]	0	0
George	2	1	1[a]	1	0
How	7	1	0	1	0
Love	1	1	0	0	0
Nan	2	1	0	0	0
Oboe	2	1	1[a]	0	0
Uncle	2[c]	1[a, c]	0	0	0
William	2	1	0	0	0
Yoke	2	1	0	1[a, c]	0
Bravo	1	1	0	0	0
Able	1	1[a]	0	0	0
YAG-39	1	1	0	0	0
YAG-40	1	1	0	0	0
LST-611	1	1	0	0	0
Rongerik	0	0	0	1[d]	1[d]

[a]Not used for Cherokee.
[b]Cherokee only.
[c]Not used for Zuni
[d]Cherokee and Zuni only.

at the same station, one was set to collect a series of 5-minute samples, while the other collected 30-minute samples; however, for stations within the possible base-surge area, 1- and 30-minute samples were collected.

Distances and azimuths of stations from ground zero for each of the Bikini shots in which the project participated are shown in Table 2.4.

In addition to the stations on Bikini Atoll, a station was established at Rongerik Atoll and was instrumented with a distant gross fallout collector (DGFC), a tape fallout monitor (TFM), and two aerosol filter samplers. Details of construction and operation are given in Section A.5 (Appendix A). These instruments were actuated manually by personnel of the Rongerik weather station. They were operated during the period from H+2 to H+26 hours for Shot Zuni.

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An intermittent fallout collector, a gross fallout collector, and a Project 2.2 dose-rate recorder were placed on the Project 2.63 instrument platforms located on the landing ship, LST-611, and the converted Liberty ships, YAG-39 and YAG-40.

Instrumentation of Eniwetok Atoll for Lacrosse was limited to Sites Leroy, Wilma, Yvonne, and Mack (Table 2.5 and Figure 2.2). Each of these stations included a gross fallout collector and a Signal Corps film packet. Since participation during Mohawk was limited to aerial survey, no stations were instrumented for the shot.

2.2 FIELD OPERATIONS

2.2.1 Installation of Equipment. Installation of equipment at the station locations was begun approximately 30 days before the ready date for the first event. Each station was located in a cleared area on the

TABLE 2.2 INSTRUMENTATION OF PROJECT 2.65 STATIONS FOR NAVAJO

Site	Intermittent Fallout Collectors (IFC)	Gross Fallout Collectors (GFC)	Base Surge Detectors (BSD)	Tape Fallout Monitors (TFM)
Charlie	5	3	0	1
Fox	1	0	1	0
George	2	1	1	1
How	5	1	0	1
Love	1	1	0	0
Nan	2	0	0	0
Oboe	2	1	0	0
Uncle	2	1	0	0
William	2	1	0	0
Yoke	2	1	0	1
Bravo	1	1	0	0
Able	1	1	0	0
YFNB-29	1	1	0	0
YAG-39	1	1	0	0
YAG-40	1	1	0	0
LST-611	1	1	0	0

part of the island site where water-wave inundation was least likely to occur, i.e., on the highest part of the island and on the side farthest from the nearest ground zero.

The arrangement of the instruments at a typical land station is shown in Figure 2.3. The intermittent fallout collectors were placed within concrete support foundations so designed that the collecting trays were approximately 2 feet 8 inches above the surrounding ground level. Where more than one collector was placed at a station, they were 10 feet apart, center to center.

Each gross fallout collector was mounted on a concrete base adjacent to the intermittent fallout collector and was bolted to one end of the foundation for the intermittent fallout collector. The opening of each collector was approximately 4 feet above ground level.

Each tape fallout monitor was bolted to the top of the foundation used for the intermittent fallout collector so that the collection surface was about 4 feet above ground level.

The base surge indicators were located in the same cleared areas, approximately 10 feet away from the other instruments.

Installation of equipment on the YFNB-29 barge is shown in Figure 2.4.

2.2.2 Aerial Survey. Aerial survey points on the islands of each atoll were located prior to the first event through the use of aerial photographs, maps, and visual reconnaissance. These points were selected on the basis of the availability of cleared areas and the proximity of these areas to the center of the island.

The aerial survey instrument described in Appendix A was calibrated before each shot on the Project 2.1 calibration range at Site Elmer. The instrument was then shipped to Bikini for installation in the survey helicopter. At the completion of the survey for each shot, the instrument was returned to Elmer, and the calibration procedure was repeated in order to make certain that no change had occurred during shipment and use in the field.

TABLE 2.3 INSTRUMENTATION OF PROJECT 2.65 STATIONS FOR TEWA

Site	Intermittent Fallout Collectors (IFC)	Gross Fallout Collectors (GFC)	Base Surge Detector (BSD)	Tape Fallout Monitors (TFM)
Charlie	2	0	0	0
Fox	0	0	1	0
George	3	3	0	0
How	5	1	0	1
Love	1	1	0	0
Nan	2	0	0	0
Uncle	2	1	0	0
William	2	1	0	0
Bravo	1	1	0	0
Able	1	1	0	0
YFNB-29	1	1	0	0
YAG-39	1	1	0	0
YAG-40	1	1	0	0
LST-611	1	1	0	0

After each shot, the survey mission began as soon as clearance was granted by Commander, Task Group 7.1. In most cases, this was at about H+7 hours. For the Bikini events, the survey began on Site Nan and proceeded around the atoll in a counterclockwise direction, ending at Oboe. For Shots Lacrosse and Mohawk, at Eniwetok Atoll, the survey mission began on Site Elmer and proceeded around the atoll until the southern chain of islands was reached. These missions were repeated on D+1 and D+2 days for each shot.

The probe was lowered through the side door of the H-19 helicopter as it hovered at an altitude of about 600 feet above a check point on the ground. When the tripod support touched the ground, the probe was at a point 3 feet above the surface, and a reading was taken. The operator then reeled in a portion of the cable, and the helicopter moved to the next check point, where the procedure was repeated. Figure 2.5 shows the probe and tripod support being lowered from a survey helicopter.

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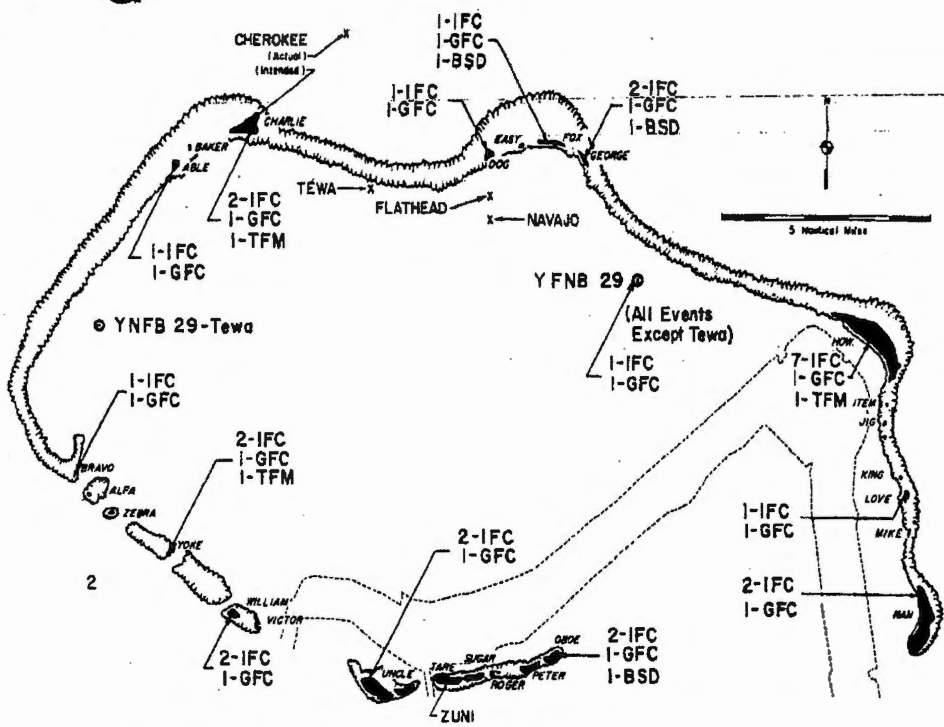

Figure 2.1 Basic station layout for Bikini Atoll.

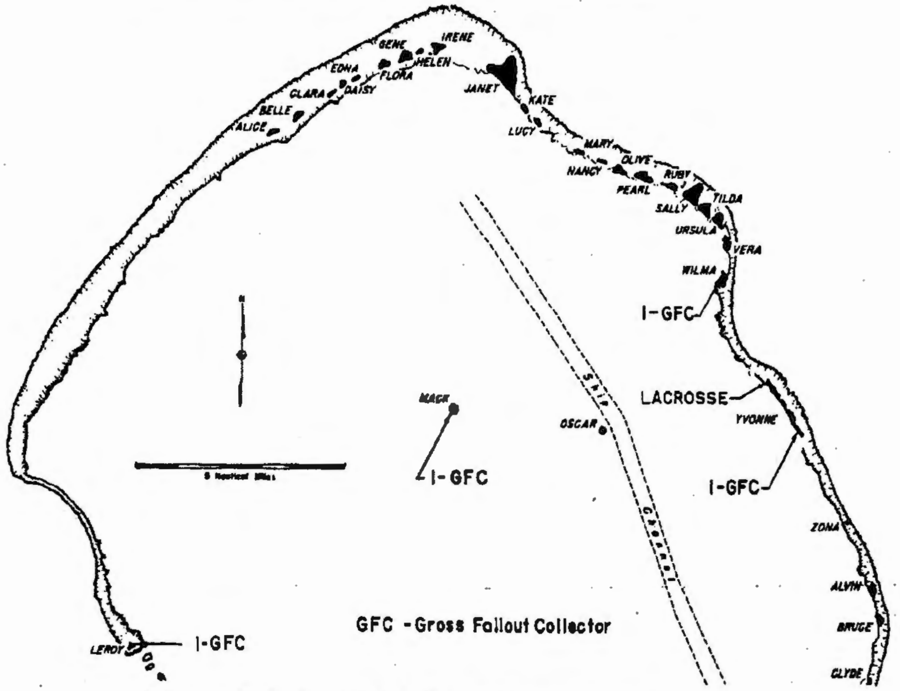

Figure 2.2 Project 2.65 stations for Lacrosse.

[redacted]

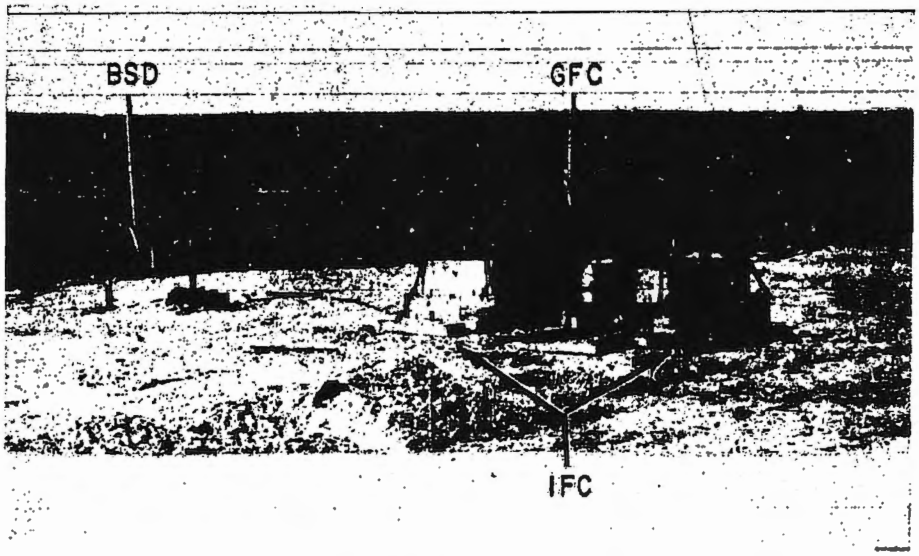

Figure 2.3 Project 2.65 station showing two intermittent fallout collectors (IFC), one gross fallout collector (GFC), and one base-surge detector (BSD).

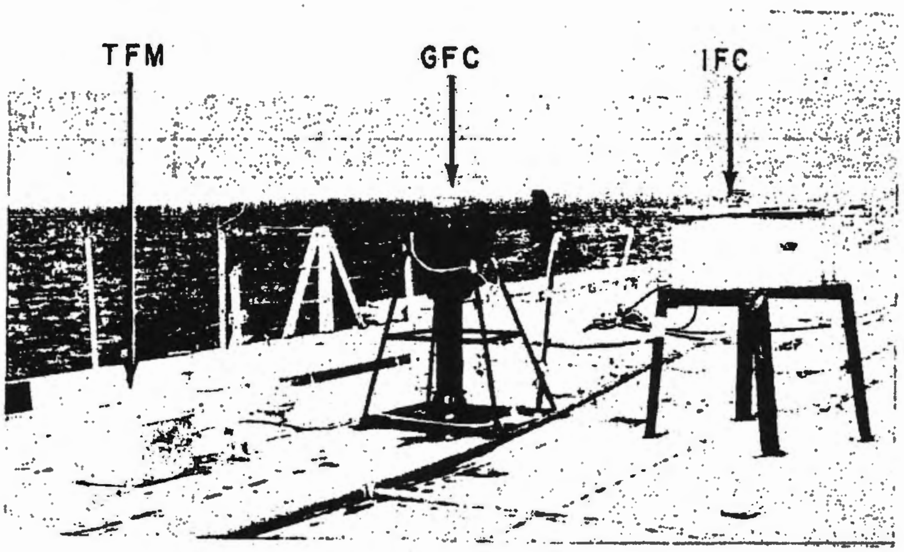

Figure 2.4 Project 2.65 station on YFNB-29, showing tape fallout monitor (TFM), gross fallout collector (GFC), and intermittent fallout collector (IFC).

[redacted]

Figure 2.5 Probe and tripod being lowered from H-19 helicopter.

Conversion factors for changing dose-rate readings for various altitudes above ground to the equivalent reading at the 3-foot level were obtained by taking gamma dose-rate readings at various altitudes above Site Charlie. These readings were obtained by raising the probe to successively higher levels as the helicopter hovered at its initial altitude. Conversion factors as obtained were not directly used for the present analysis, which uses the readings taken at 3 feet. These data, combined with other factors which take into account the geometry of the activity will eventually provide a basis for correlation between readings taken at an altitude above the ground and those taken at 3 feet.

For Shots Lacrosse, Mohawk, and Zuni, readings were taken as close to the crater as was consistent with safety to personnel in the helicopter.

2.2.3 Recovery of Samples. Two gross fallout samples were recovered by helicopter on D-day for each Bikini shot. These samples were obtained as early as possible, so that early decay measurements could be started. The remaining samples from the gross fallout collectors, the intermittent fallout collectors, and the tape monitors on the island stations were recovered on D+1 day after each event. Samples from the LST and the two YAG's were recovered as soon as they returned to the Bikini or Eniwetok Lagoon.

For the Bikini events, the island samples were brought to Site Nan, where they were prepared for shipment to Eniwetok. All samples arrived at the field laboratory on Site Elmer (of Eniwetok Atoll) by D+2.

For Shot Lacrosse, all samples were available for analysis on D+1 day.

[redacted]

2.3 ANALYTICAL PROCEDURES

2.3.1 Aerial Survey. The raw aerial survey data were corrected by means of the instrument calibration curves which were obtained prior to each shot. Details of the calibration procedure, along with a typical calibration curve, are given in Appendix A. Field gamma decay curves were taken then drawn for several of the islands included in the survey by use of the values obtained between D-day and D+2 days. The decay exponent for each set of readings was then obtained, and the average value was used for correction of the measured dose-rate readings to the equivalent H+1 hour values.

Conversion factors for changing dose-rate readings for various altitudes above ground to the equivalent reading at the 3-foot level were obtained by the plotting of the ratio of ground reading to altitude reading against probe height above ground.

2.3.2 Weight and Activity of Fallout. The intermittent fallout samples which were dry were carefully brushed from each tray into the attached bottle, and the total weight of the sample was determined by standard balance techniques. A portion of each sample to be used for activity analysis was then placed in a previously weighed, stainless-steel cup and the weight determined. The amount of the sample taken was kept between 5 and 10 mg, in order to minimize self-absorption in the sample. The sample was then counted in precision beta-counting equipment. The counting equipment and procedures and the corrections necessary for determining activity in disintegrations per minute are described in Appendix B.

Intermittent-fallout samples which contained both liquid and solid were filtered using the Fisher filtrator and Whatman No. 42 filter paper. The filter paper was ashed, and the weight of the residue was determined. Portions were then taken for activity analysis as described above. The total volume of the filtrate was obtained and aliquots of from 1 to 1,000 lambda* (depending on the specific activity) were pipetted into stainless-steel counting cups. These cups were dried under infrared lamps and counted in the usual manner.

Samples from the gross-fallout collectors were first weighed and an aliquot taken for beta activity per unit weight. These samples were treated in the same manner as the IFC samples described above. Weight and activity per unit area of sampling surface were then plotted as a function of particle size.

The portion of several gross-fallout-collector samples remaining after aliquots were taken for beta activity per unit weight, beta decay, and gamma-dose-rate decay were size-separated with U. S. standard sieves. The sieving separated the particles into the following size ranges: 0 to 44 μ, 44 to 74 μ, 74 to 105 μ, 105 to 149 μ, 149 to 210 μ, 210 to 420 μ, 420 to 840 μ, and greater than 840 μ. All size ranges were weighed, and an aliquot of each was placed in a stainless-steel counting cup and weighed again. From these weights and the activity of the aliquots, activity versus particle size for the fallout samples was obtained.

*1 lambda = 10^{-6} liters.

[redacted]

TABLE 2.4 DISTANCES IN FEET AND AZIMUTHS OF PROJECT 2.65 STATIONS FROM GROUND ZERO FOR BIKINI SHOTS

Station	Zuni	Flathead	Navajo	Tewa
Able	78,340 330°	46,120 275°	46,400 278°	29,090 276°
Charlie	78,080 338°	36,780 287°	37,790 289°	20,420 299°
Dog	69,920 5°	5,640 2°	8,050 1°	—
Fox	72,720 13°	11,960 54°	13,470 46°	—
George	71,800 17°	15,070 71°	15,970 63°	31,690 84°
How	77,210 52°	56,670 107°	56,000 104°	72,240 105°
Love	72,240 70°	73,020 124°	71,160 123°	88,020 118°
Nan	68,770 86°	86,150 134°	84,490 133°	99,360 128°
Oboe	16,310 78°	62,150 172°	58,680 172°	—
Uncle	10,500 259°	68,010 194°	65,690 195°	64,530 179°
William	35,000 285°	78,100 213°	75,320 214°	59,400 199°
Yoke	43,100 293°	66,630 224°	64,200 225°	56,240 210°
Bravo	59,800 298°	67,960 238°	68,770 239°	56,820 227°
YFNB-29	55,300 32°	28,440 124°	28,440 120°	41,400 235°
YAG-39	480,480 350°	153,120 8°	105,600 351°	121,440 335°
YAG-40	279,840 2°	311,520 22°	174,240 339°	211,200 307°
LST-611	—	158,400 318°	232,320 265°	290,400 322°

TABLE 2.5 PROJECT 2.65 STATIONS FOR LACROSSE

Island	Coordinates (Holmes and Narver)		Distance From Ground Zero	No. of Gross Fallout Collectors	No. of Film Packets
	N	E	ft		
Wilma	110,920	110,800	14,000	1	1
Yvonne	100,010	120,910	8,000	1	1
Leroy	70,170	30,240	97,500	1	1
Mack	100,370	80,640	37,500	1	1
Gene	148,820	71,180	69,000	0	0

[redacted]

2.3.3 Particle-Size Measurements. Portions of all size-graded samples were placed on NTB stripping film mounted on plastic rings for radioautography. A mixture of xylene and silicone was added to hold the sample in place, and the sample was exposed for 24 hours. All NTB film was processed at the test site and returned to the Army Chemical Center for analysis. Particle-size distributions and the ratio of active to inactive particles in each size range will be determined.

2.3.4 Decay Measurements. Measurements of beta decay were taken for all intermittent-fallout collector intervals which contained samples counting 1,000 counts per minute or more at initial counting.

Aliquots from gross-fallout collectors were used for beta decay measurements, as well as for gamma decay measurements.

The sample to be measured was transferred to a stainless-steel counting cup for beta-decay measurements and to a glass planchet for gamma dosage decay measurements. It was then immobilized with a small amount of silicone resin diluted with toluene in order to facilitate counting and handling procedures.

The counting technique for beta decay measurements is described in Appendix B. The counting for gamma dosage decay measurements was done using a Jordan AGB-10-SR survey meter with the sample placed in a fixed geometry 1 inch away from the meter surface. The AGB-10-SR survey meter is the same as the AGB-10K-SR meter, described in Appendix A, except that the upper range limit is 10 r/hr.

Decay measurements were begun at H+24 hours or less and continued at the test site for a period ranging from 100 to 1,000 hours. The samples were then returned to the Army Chemical Center, where the analysis was continued. For the first 100 hours, the samples were counted once every 24 hours. At later times they were counted every other day.

Curves of field gamma-dose-rate decay were plotted from aerial and ground survey data taken at the same locations on successive days from H+8 hours to H+50 hours.

2.3.5 Time of Arrival, Rate, and Duration of Fallout. The time of fallout arrival at each station was determined from the analysis of the samples collected by the intermittent fallout collector and from the tape monitor data.

Samples from the intermittent fallout collectors were prepared and counted with precision beta counting equipment, as described previously in Section 2.3.2.

Counting was begun at about H+50 hours, and all activities were corrected back to this standard time. The decay exponent used for this purpose was derived from the early beta decay curves obtained from these samples. Counts per minute were converted to disintegrations per minute, as described in Appendix B.

The total activity per sampling interval was then plotted as a function of time. From these graphs, the time of arrival, the time for the maximum rate of fallout, and the time at which significant fallout ends were determined.

Additional time of arrival data were determined from the tape fallout monitor. Relative activities were determined by monitoring the individual sections of the tape with a Beckman MK-5 G-M survey meter.

A constant geometry was maintained through the use of a special mount for the meter and sample. These data were used only for determining activity peaks.

2.3.6 Base-Surge Phenomena. The records obtained from the base-surge detectors were inspected to determine whether any changes in the intensity of the light beam reaching the photovoltaic cell occurred during the time intervals of interest. Where a decrease in the light intensity occurred, the records were evaluated to determine the probable cause of the change. By comparison of the time and duration of the decrease in light intensity with the estimated times of arrival of the blast wave, possible water wave, or base surge, the existence or absence of a surge can possibly be deduced.

Further indications of the significance of the base surge, its role in the transport of radioactivity, and the mechanism by which it becomes contaminated will depend upon the results of radiochemical analysis for Sr^{89} and Ba^{140}, which have gaseous precursors, and a comparison of these concentrations with those of Mo^{99} and Ce^{144}. It is assumed that the base surge will be deficient in gaseous-precursor fission products.

2.3.7 Radiochemistry. Samples of solid gross fallout, when obtained in sufficient amount, were separated by U. S. standard sieves into the following size ranges: 0 to 44 μ, 74 to 105 μ, 105 to 149 μ, 149 to 210 μ, 210 to 420 μ, 420 to 840 μ, and greater than 840 μ. Where the 0-to-44 μ fraction was sufficiently large, a further separation was effected by the roller analyzer into the following size ranges: 0 to 5 μ, 5 to 14 μ, 10 to 22 μ, 16 to 32 μ, and 26 to 44 μ. The roller analyzer has certain limitations in that it has a tendency to break up the particles, but no other method was available to obtain large samples in this particle size region. A weighed portion of each size fraction dissolved in hydrochloric acid. The remainder of each fraction was reserved for measurement of particle-size distribution, determination of percent of active particles, chemical microscopy, and thin-section work.

(b) (3)

Analyses for Sr^{89}, I^{131}, Ba^{140}, Ce^{144}, and in some cases Ca^{45} are in progress at the Army Chemical Center.

Similar radiochemical analyses were performed on selected solid samples which were too small to size-grade and on liquid samples. Emphasis was placed on time-incremental samples and on samples collected at various distances from ground zero.

(b) (3)

Complete gamma spectra and Sr^{90}/Ba^{140} ratios are being determined at the Army Chemical Center on selected gross fallout samples.

2.3.8 Examination of Individual Particles. Samples selected for study were first examined under the microscope. A Bausch and Lomb stereoscopic microscope was used throughout this work. Aliquots were encased in transparent, plastic mounts. The mounts were ground down by petrographic techniques until about half of each particle remained, so that

[redacted] [redacted]

the cross sections were revealed. The numbers of particles of various types were counted under the microscope. Photomicrographs were made on Kodak Plus X and Ektachrome film with a Leica camera and accessories.

Radioautographs were made by placing the plastic mounts in contact with Kodak metallographic plates for periods ranging from 1/2 to 7 minutes. Plates were developed in accordance with the manufacturer's instructions. The radioautographs were matched over the corresponding plastic mounts and examined under the microscope. The number of radioactive particles for each particle type was determined, and the particles were designated as active throughout or as active only on the surface.

Because of the coral and salt water environment, the chemical species to be expected in macro-quantities in fallout from shots in the Pacific Proving Ground are limited to a few compounds. Hence, only a small number of tests are needed to complete a gross chemical characterization of the particles. These tests were applied to individual, sectioned particles under the microscope. A basic reaction to phenolphthalein indicated the presence of calcium oxide or calcium hydroxide. Bubbling upon the addition of 1 M nitric acid served as an indication of calcium carbonate. The silver nitrate test was used for chloride ion. Potassium ferrocyanide and potassium thiocyanate were used to test for iron. Ferromagnetism was tested by bringing a small magnet near to loose particles while the particles were viewed with a microscope.

The bulk density of fallout samples was determined through the use of a pycnometer. The detailed procedure is given in Appendix B.

[redacted] - [redacted]

CHAPTER 3

RESULTS AND OBSERVATIONS

Useful data were obtained by this project following each of the shots in which participation was planned except for Shot Cherokee. The yields and locations of these shots are tabulated in Table 3.1.

No fallout was observed over the Bikini Atoll following the Cherokee air drop. All fallout collectors were monitored, nevertheless, and an earth sample was scooped from the area of the intended ground zero. This sample, as well as those from the collectors, showed no activity resulting from the event. Since the actual ground zero was over water and not upwind from the atoll, no data were obtained relative to the presence of contamination following a megaton-range air burst.

TABLE 3.1 EVENTS IN WHICH PROJECT 2.65 PARTICIPATED

Shot	Atoll	Type of Shot	General Location	Preliminary Yield
Lacrosse	Eniwetok	Land Surface	Yvonne	(b) (3)
Cherokee	Bikini	Air Drop	NE of Charlie	
Zuni	Bikini	Land Surface	Tare	
Flathead	Bikini	Barge	Lagoon Off George	
Mohawk	Eniwetok	300-ft Tower	Ruby	
Navajo	Bikini	Barge	Lagoon Off Dog	
Tewa	Bikini	Land Surface	Over reef between Charlie and Dog	

Dose-rate contours within the area of the atolls have not yet been constructed by this project for any of the events listed in Table 3.1. For Shot Lacrosse no data were collected for the water area of the lagoon. For the Bikini events, dose-rate data were obtained for the water area within the lagoon by Projects 2.62 and 2.63. It is anticipated that these data will have been reduced to the equivalent infinite plane land-surface readings in time for inclusion in the final report of Project 2.65.

The field equipment used by this project operated satisfactorily in most cases. In those instances where intermittent and gross fallout collectors failed to function, the difficulty was usually due to failure of the blue boxes to trigger the circuits involved. Despite these failures, more than 75 percent of the collectors operated satisfactorily for Shots Lacrosse, Zuni, Flathead, Navajo, and Tewa.

Operational difficulties were experienced with the base surge detectors, due to the effect of the shock wave in some cases and to the fact that the H-1 minute signal was not received at the station in one instance. In another case, the station was not instrumented, because of the predicted height of the water wave.

After two of the events, useful samples were obtained from sources other than the fallout collectors. After Shot Lacrosse, ground scoop samples were obtained from Sites Wilma and Gene, and another was retrieved from a depression in the canvas top of an abandoned truck at Gene. After Shot Zuni, a large sample was scooped from the forward deck house of the YAG-40 following the ship's return to Bikini Lagoon on D+2 day.

No useful samples were obtained at the distant fallout station at Rongerik Atoll. The station there was not activated for any shot except Zuni. After the Zuni event, the inside liner of the total fallout collector was returned to Site Elmer and surveyed for beta plus gamma activity with an MX-5 survey meter. An insignificant amount of activity was noticed. Brushing the liner yielded no useful solid fallout sample. Post-shot examination of available records revealed that there was, in fact, no significant fallout at Rongerik.

3.1 DECAY MEASUREMENTS

3.1.1 Gamma-Dose-Rate Decay. Early field gamma dose rate decay curves resulting from aerial survey data are shown in Figures 3.1 to 3.5. These curves, based upon the measurements made on D-day, D+1, and D+2, reflect the field decay rate for the period from H+8 hours to H+50 hours. A straight line was fitted to the three points by inspection, and the slope of the line was determined by measurement from the graph. No field decay curves were obtained for Navajo, because of the effect of the heavy rains which occurred on D+1 day.

Laboratory gamma dose rate decay measurements obtained from selected gross fallout collector samples for each shot are shown in Figures 3.6 to 3.10. The time interval covered was from approximately 20 hours to several hundred hours.

In general, all gamma dose rate decays for Shot Lacrosse were similar to that shown in Figure 3.6 for the solid sample obtained from the gross fallout collector on Site Wilma. The liquid sample from this same collector exhibited a markedly different decay, as shown in Figure 3.7. This difference cannot be explained at this time.

All Shot Zuni samples exhibited similar decay curves between H+40 and H+600 hours. A representative gamma decay curve from Zuni gross fallout is shown in Figure 3.8.

A gamma dose rate decay curve from Shot Flathead is shown in Figure 3.9 and one from Shot Navajo in Figure 3.10. Some samples show deviations from these decay curves. Later analysis of all decay data will provide information which may make possible the construction of a composite decay curve for each shot. Consequently, no curves have been drawn through the data points presented in the figures. In addition, due to the preliminary nature of the data, the counting errors have not been evaluated.

The decay slope determined from these graphs of gamma dose rate decay for Shots Lacrosse, Zuni, Flathead, and Navajo are listed in Table 3.2.

The slopes listed for the Zuni and Navajo curves are based upon the straight line passing through the first three points which cover the period from H+20 to H+50 hours. This time period was used in the table in order that the laboratory and field measurements would cover the same period.

3.1.2 Beta Decay. Beta decay data were obtained from gross fallout collector samples and from all intermittent fallout collector samples having sufficiently high activities. Representative decay curves for each shot are shown in Figures 3.11 to 3.16. Curves for both liquid and solid

TABLE 3.2 EARLY GAMMA-DOSE-RATE DECAY SLOPES

	Lacrosse	Zuni	Flathead	Mohawk	Navajo	Tewa
Field Gamma Decay Slope (H+8 to H+50 hours)	-1.36	-0.92	-1.0	-1.1	—[b]	-1.08
Laboratory Gamma Decay Slope (H+20 to H+50 hours)	-1.33	-0.90	-1.2	—[a]	-1.02	—[c]

[a]Samples not collected for this shot
[b]Heavy rains prevented evaluation of field decay slope.
[c]High background at Site Elmer prevented determination.

fallout samples are included for Shots Lacrosse and Zuni. In each case, appreciable differences are observed in the shape of the curves for the two types of samples. The decay curve for Flathead, shown in Figure 3.15, is representative of those liquid and solid samples which had relatively high activity at the time of initial counting.

3.2 AERIAL SURVEY DATA

All survey data were corrected through the use of the instrument calibration curves obtained immediately prior to each event. The calibration procedure and a typical calibration curve are included in Appendix A.

3.2.1 Shot Lacrosse. The aerial survey readings obtained on Sites Zona through Daisy are shown in Table 3.3. The H+1 hour dose rates were determined by using a decay exponent of -1.36 as obtained from the field gamma decay curves of Figure 3.1. These H+1 hour values are shown on a map of the atoll (Figure 3.22).

Aerial survey readings were not obtained on Site Alice, and the value shown was calculated from Rad-Safe ground readings.

All survey readings taken over the reef near the crater were obtained during low tide. The reef had been washed over by at least two high tides between shot time and time of the survey. The calculated H+1 hour dose rates for Site Yvonne and the adjacent reef are shown in Figure 3.18. The one abnormally high reading near the edge of the crater lip was obtained on D+1 day. No other comparable dose rate levels were observed during the survey. The crater was partially filled with water at all times, and no readings were attempted over the crater or lip.

3.2.2 Shot Zuni. Aerial survey readings obtained on islands of Bikini Atoll after this shot are shown in Table 3.4. The H+1 hour dose rates were determined by using a decay exponent of -0.92, obtained from

TABLE 3.3 CORRECTED AERIAL SURVEY READINGS, LACROSSE
(field gamma decay exponent: -1.36)

Site	Survey Point	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 hr Dose Rate
		hr	mr/hr	r/hr	r/hr
Zona	1	7.25	170	2.5	
Yvonne	1	7.3	170	2.5	
	2	9.25	120	2.5	
	3	9.3	1,700	35.4	
	4	26.17	2,400	202	
	5	50.25	210	44.2	
	6	50.3	7,500	1,580	
	7	26.25	56,000	4,760	
	8	26.3	44,000	3,740	
	9	26.83	650,000	57,000	
	10	50.83	8,000	1,750	
	11	50.5	2,500	540	
	12	50.58	650	140	
Wilma	1	7.5	710	11.0	
	2	26.1	320	27.0	
		50.7	90	20.0	23.7[a]
	Grd Rdg at CPC station	10.1	800	24.4	
	Grd Rdg at ocean side	54.0	90	23.2	
Tilda	1	7.58	4,800	75.3	
		26.0	1,100	92.5	80.3
		50.58	340	73.0	
Pearl	1	7.7	5,900	94.5	
		26.0	1,200	101	97.4
		50.5	450	96.8	
Janet	1	7.75	7,000	113	
		25.83	1,350	114	115
		51.4	520	117	
Daisy	1	7.83	13,200	218	
		25.65	3,100	256	219
		50.28	850	184	

[a] The reading at survey point Number 1 was disregarded in calculating the average H 1 hr dose rate. This station was too close to the edge of the water for the reading to be considered reliable.

the field gamma decay curves of Figure 3.2. These H+1 hour values are shown on a map of Bikini Atoll (Figure 3.19).

No D-day survey readings are reported for Sites William, Uncle, or Peter, because of instrument malfunction during the latter part of the atoll survey. After the return from the survey mission, a loose connection in the probe cable was found to be responsible. No readings were obtained on Sites Roger, Sugar, Tare, or the eastern end of Uncle, because of the safety limitations imposed by the Commander, Task Group 7.1.

3.2.3 Shot Flathead. Survey readings following this shot are shown in Table 3.5. The H+1 hour dose rates for this event were determined by using a decay exponent of -1.0, obtained from the field gamma decay curves of Figure 3.3. These H+1 hour values are shown on a map of Bikini Atoll in Figure 3.20.

The southern island sites from Bravo through Oboe were surveyed but, along with Sites Nan through How, showed no increase in contamination over the levels which existed prior to Shot Flathead.

[redacted] [redacted]

TABLE 3.4 CORRECTED AERIAL SURVEY READINGS, ZUNI
(field gamma decay exponent: -0.92)

Site	Survey Point	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 hr Dose Rate
		hr	mr/hr	r/hr	r/hr
Love	1	8.1	130	0.89	1.2
		32.75	50	1.2	
		56.0	40	1.6	
How (South)	1	8.2	700	4.9	5.7
		33.0	290	7.2	
		56.1	120	4.9	
How (Center)	2	8.25	1,400	9.8	11
		33.0	470	11.7	
		56.1	280	11.4	
George	1	8.4	12,000	85	91
		33.2	3,700	93	
		56.3	2,300	94	
Fox	1	8.5	13,000	72	93
		33.3	4,300	108	
		56.3	2,400	98	
Dog	1	8.5	13,000	72	89
		33.3	4,000	101	
		56.3	2,300	94	
Charlie (Center)	1	33.4	4,000	101	96
		56.4	2,200	90	
Charlie (Northeast)	2	8.75	11,000	81	86
		33.5	3,700	94	
		56.5	2,000	82	
Able	1	8.9	12,000	90	82
		33.5	3,100	78	
		56.6	1,900	78	
Bravo	1	9.1	3,100	24	22
		33.7	820	21	
		56.8	530	22	
Zebra	1	9.2	2,700	21	21
		33.8	870	22	
		56.8	500	21	
William	1	33.9	1,600	41	40
		56.9	920	38	
Uncle (West end)	1	34.0	980	25	26
		57.0	620	26	
Oboe	1	34.1	1,500	39	38
		57.1	870	36	

3.2.4 Shot Mohawk. The aerial survey covered the portion of Eniwetok Atoll which was contaminated to a significant extent by this event. This included the sites between Janet and Sally. The largest number of readings was taken on the close-in sites, Pearl, Ruby, and Sally. Since Pearl and Sally were the sites of previous detonations, varying contamination levels existed on portions of these islands prior to Mohawk. Therefore, the H+1 hour dose rates due to Mohawk were not calculated in these instances. For Sites Olive through Janet, the actual readings were corrected by subtraction of the small dose rates existing prior to the shot. The preshot readings on the south end of Pearl and the north end of Sally were negligible when compared to the post-Mohawk readings.

[redacted]

TABLE 3.5 CORRECTED AERIAL SURVEY READINGS, FLATHEAD
(field gamma decay component: -1.0)

Site	Survey Point	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 hr Dose Rate
		hr	mr/hr	r/hr	r/hr
Able	1	9.28	8,800	85	
		32.3	2,800	98	93
		55.9	1,600	97	
Charlie (Station)	1	9.0	18,000	169	
		32.1	5,000	171	172
		55.8	2,900	175	
Charlie (Ground Zero)		9.2	18,000	173	
	2	32.1	5,200	178	172
		55.8	2,700	164	
Dog	1	8.83	19,000	176	
		31.9	5,600	192	187
		55.7	3,200	192	
Easy	1	8.77	16,000	146	
		31.9	5,000	171	156
		55.6	2,500	150	
Fox	1	8.74	12,000	110	
		31.8	2,700	92	99
		55.6	1,600	96	
George	1	8.68	6,500	59	
		31.6	2,000	68	58
		55.5	800	48	

Table 3.6 shows the corrected readings and the equivalent H+1 hour readings due to the shot. A decay exponent of -1.1 was obtained from the field gamma decay curves of Figure 3.4. These H+1 hour values are shown in Figure 3.21. The calculated H+1 hour dose rates for the area near the crater are shown in Figure 3.17.

3.2.5 Shot Navajo. Aerial survey of Bikini Atoll following this shot covered the island sites between How and Bravo. Negligible levels of contamination resulting from this shot were observed on other sections of the atoll. The result of the D-day and D+1 day survey is shown in Table 3.7. Extremely heavy and steady rains occurred between the D-day survey and the D+1 day survey. The table shows that the D+1 day reading is very low, compared to the D-day readings. Because of the apparent effect of the rain and of the short lead time announced for the next event, no D+2 day readings were obtained. A gamma decay exponent of -1.02, determined from laboratory gamma decay measurements for early times, was used in converting the D-day readings to H+1 hour values.

Although the islands shown had some contamination remaining from previous shots, those with the highest preshot levels were subjected to the effect of high blast overpressures and to water wave action prior to the arrival of fallout. The H+1 hour dose rates resulting from Navajo are shown in Figure 3.23.

3.2.6 Shot Tewa. Survey readings following this shot are given in Table 3.8. The H+1 hour dose rates for this event were determined by the use of a decay exponent of -1.08, obtained from the field gamma decay

TABLE 3.6 CORRECTED AERIAL SURVEY READINGS, MOHAWK
(field gamma decay exponent: -1.10)

Site	Survey Point	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 hr Dose Rate
		hr	mr/hr	r/hr	r/hr
Janet	1	9.43	985	11.6	
		31.5	285	13.4	12.0
		55.6	135	11.1	
Kate	1	9.48	985	11.7	
		31.6	275	13.0	11.9
		55.7	135	11.1	
Lucy	1	9.53	935	11.1	
		31.6	335	15.0	12.7
		55.7	145	12.0	
Mary	1	9.58	135	1.80	
		9.88	125	1.74	
		31.7	45	2.02	1.70
		55.8	15	1.25	
Olive (North)	1	9.92	35	0.42	
		9.63	35	0.42	
		31.7	15	0.67	0.50
		55.8	5	0.41	
Olive (South)	1	9.95	110	1.38	
		31.8	50	2.24	2.71
		55.9	55	4.50	
Pearl (North)	1	9.97	1,700	a	a
		31.8	2,700	a	a
		55.9	3,000	a	a
Pearl (Center)	1	9.97	1,200	a	a
		31.8	600	a	a
		56.0	150	a	a
Pearl (South)	1	10.0	50,000	627	
		10.0	48,000	603	
		31.8	22,000	990	755
		56.0	9,500	798	
Sally (Center)	1				
		32.4	4,300	b	b
		56.4	3,500		
Sally (North)	1	9.33	41,000	478	
		32.4	12,000	550	473
		56.4	4,600	391	
Ruby	1	31.8	34,000	1,560	
	2	31.9	50,000	2,250	
	3	32.2	180,000	8,290	
	4	31.9	200,000	8,990	
	5	32.2	250,000	11,500	
	6	32.3	230,000	10,600	
	7	32.3	215,000	9,900	
	8	32.3	84,000	3,870	
	9	32.3	285,000	13,100	
	10	32.4	285,000	13,200	
	11	56.1	78,000	6,550	
	12	56.1	110,000	9,230	
	13	56.1	105,000	8,810	
	14	56.2	130,000	10,900	
	15	56.2	100,000	8,400	
	16	56.3	150,000	12,600	
	17	56.3	130,000	10,900	

[a] These readings were not extrapolated to H+1 hr due to uncertainty of residual contamination from Shot Inca.
[b] These readings were not extrapolated to H+1 hr due to uncertainty of residual contamination from Shots Kickapoo and Yuma.

curves of Figure 3.5. These H+1 hour values are shown in Figure 3.24.

Sites George through Able were not surveyed on D-day in conformance with task group safety regulations concerning this project's aerial survey over areas of extremely high contamination levels. On all islands, the contamination remaining from previous shots was negligible as compared with the high contamination levels existing after this shot. The decay exponent determined from Figure 3.5 for Site Bravo was not included in the average value of -1.08, due to its large variation from that of the other islands. Extremely heavy rains followed this shot, as on Navajo. However, there was no apparent change in decay rates due to this rain.

3.3 VARIATION OF DOSE RATE WITH HEIGHT ABOVE SURFACE

Conversion factors for changing dose-rate readings for various altitudes above ground to the equivalent readings at the 3-foot level for Zuni and Flathead are shown in Figures 3.25 and 3.26. The Zuni data were obtained at approximately H+54 hours, while the Flathead data were obtained at H+9 hours. No explanation can be given at this time for the differences in the two curves.

3.4 TIME OF ARRIVAL, RATE, AND DURATION OF FALLOUT

The time of arrival and rate of fallout were determined primarily from intermittent fallout collector data. The tape fallout monitor did not operate successfully for Zuni, although records were obtained from one instrument for Shots Flathead and Tewa.

In general, the times of arrival and ending of fallout, as given in the following sections, represent the times for arrival and cessation of significant fallout activity. In all instances, small amounts of activity were collected earlier than the stated time of arrival and continued for periods later than the stated time of ending. The rate of fallout for these early and late periods was generally less than the maximum rate by a factor of 100 or more. All intermittent fallout collector data presented in this section are expressed in terms of beta disintegrations per minute for the total sample collected in the 18-in^2 trays. All activities were corrected to H+50 hours, since this was the approximate time at which counting was started. The decay exponent used was that found for the individual shots and reported in Section 3.1.

<u>3.4.1 Shot Zuni.</u> The activity collected during each 1-minute sampling interval by the collector on Oboe is shown graphically in Figure 3.27. Although some activity was collected during the first minute and during the period from 2 to 4 minutes, much larger quantities were collected between 16 and 20 minutes after shot.

Similar data resulting from collectors using 5- and 30-minute sampling intervals at the stations on Sites William, Yoke, and Charlie are plotted in Figures 3.28 to 3.33. In each case, the time of arrival and the maximum rates of fallout, as determined by the two different collectors at each station, are in close agreement—even though discrepancies

TABLE 3.7 CORRECTED AERIAL SURVEY READINGS, NAVAJO
(laboratory gamma decay exponent: -1.02)

Site	Day	Time After Shot	Corrected Reading	H+1 hr Dose Rate
		hr	mr/hr	r/hr
How	N	6.97	110	0.8
	N+1	34.6	10	
George	N	7.12	4,500	33.6
	N+1	34.7	170	
Fox	N	7.17	6,000	45.0
	N+1	34.8	520	
Dog	N	7.32	8,000	61.6
	N+1	34.8	125	
Charlie	N	7.43	6,000	46.9
	N+1	34.9	130	
Able	N	7.53	6,200	49.1
	N+1	35.0	280	
Bravo	N	7.72	230	1.9
	N+1	35.2	52	

TABLE 3.8 CORRECTED AERIAL SURVEY READINGS, TEWA
(field gamma decay component: -1.08)

Site	Day	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 Reading
		hr	mr/hr	r/hr	r/hr
Uncle	T	8.98	4,000	43	
	T+1	32.5	1,000	43	42
	T+2	57.1	500	39	
William	T	9.17	19,000	210	
	T+1	32.4	6,500	280	230
	T+2	57.0	2,500	195	
Zebra	T	9.28	38,000	420	
	T+1	32.3	9,200	395	425
	T+2	56.8	5,900	465	
Bravo	T	9.33	19,000	210	
	T+1	32.3	9,200	395	320
	T+2	56.8	4,600	360	
Able	T+1	32.1	37,000	1,570	1,455
	T+2	56.6	17,000	1,335	
Charlie	T+1	32.0	37,000	1,570	1,485
	T+2	56.5	18,000	1,400	
Dog	T+1	31.9	16,000	670	630
	T+2	56.4	7,500	585	
Easy	T+1	31.8	15,000	630	580
	T+2	56.3	6,800	530	
Fox	T+1	31.8	13,000	545	470
	T+2	56.1	5,000	390	
George	T+1	31.7	7,400	310	325
	T+2	56.1	4,300	335	

may exist in regard to actual quantities of activity collected. Cumulative activity as a function of time after shot for the Charlie station is shown in Figure 3.34. The reason for the branch between the curves for the two collectors is not understood.

The fallout arrival data for Sites Oboe, William, Yoke, and Charlie are summarized in Table 3.9. The times of arrival and maximum rates were read directly from the graphs of the 5-minute-interval collector data for William, Yoke, and Charlie. The time of cessation was read from the graphs of the 30-minute-interval collector data for these stations.

Similar data were not available for Sites Dog, Fox, and George, because the collectors at these stations did not operate. The data obtained from the instruments at the station on How, where the fallout

TABLE 3.9 TIME, RATE, AND DURATION OF FALLOUT FOR SHOT ZUNI

Site	Distance From Ground Zero	Azimuth From Ground Zero	Time of Arrival	Time to Maximum Rate of Fallout	Time of Cessation
	ft	deg	min	min	hr
Oboe	16,310	80	16-17	19-20	
William	35,000	286	15-20	25-30	2-2.5
Yoke	43,000	293	30-35	35-40	1-1.5
Charlie	78,000	336	40-45	85-90	3-3.5

activity was relatively low, showed little correlation from one collector to another.

3.4.2 Shot Flathead. Twenty five of the 33 intermittent fallout collectors used for this event operated successfully. Significant levels of fallout were observed only on Sites Able through George. At all stations on these islands, fallout was collected during the first 30 minutes after shot. A more precise determination of time of arrival cannot be made, since quantitative agreement was not obtained between instruments using different sampling intervals at the same locations. In general, the overall level of activity of the samples collected in the intermittent fallout collector for Flathead was lower by two orders of magnitude than the level of similar samples collected after Zuni. This was true in spite of the fact that the levels of contamination produced on the islands in question were of the same order for the two events. A discussion of the reasons for this apparent anomaly is included in Section 4.5.

Data resulting from 30-minute-interval collectors on Charlie and George are shown in Figures 3.35 and 3.36. These data indicate that the maximum rate of collection of fallout occurred between $1\frac{1}{2}$ and 2 hours after shot.

The survey readings obtained from the record of the tape fallout monitor on George are plotted in Figure 3.37. The record indicates that the fallout stopped at H+10 hours and started again at approximately H+$15\frac{1}{2}$ and continued until H+18 hours. The value plotted for the first 56 minutes was obtained by summing the values obtained from the 2-minute-interval samples collected during this period. Small amounts of activity were recorded for each of these early intervals.

[redacted] [redacted]

3.4.3 Shot Navajo. The contamination resulting from this detonation covered the island sites between Bravo and How (Figure 3.23). Relatively high levels were found only on Sites Able through George. The stations on Fox and George were washed onto the reef by the water wave. Thus the land stations within the fallout area which collected useful samples were those on Charlie, Able, and Bravo.

The arrival of fallout as a function of time at Charlie is represented graphically in Figures 3.38 and 3.39. The relative activity per sampling tray for the 5-minute-interval collector was determined on the basis of survey-meter readings. Prior to the shot, this collector was tilted at a 34-degree angle to the horizontal and turned to face the surface wind direction, as discussed in Section 3.5. Much larger quantities of fallout were collected in this instrument than in those which were left in the usual horizontal position. These samples were returned to the Army Chemical Center for further analysis. The time of arrival of significant fallout activity at Charlie is shown by Figure 3.38 to have been between 30 and 35 minutes. The time period during which fallout occurred at its maximum rate was between 45 and 50 minutes. The quantities of fallout collected in other instruments using 5-minute-collection intervals were so small that arrival data determined from them are inconclusive. Figure 3.39 shows the activity collected in the Charlie instrument for 30-minute intervals and indicates that significant fallout ended between $1\frac{1}{2}$ and 2 hours after the detonation.

3.4.4 Shot Tewa. The contamination resulting from this shot covered sites from How to Oboe. The only site in the fallout zone from which a sample could be recovered on D-day was How. The remainder of the sites were recovered on D+1 and D+2 with the exception of Charlie and Able, which were contaminated to such high levels as to make recovery inadvisable. The arrival of fallout as a function of time for the YFNB-29 and Sites Yoke, William, and George are represented graphically in Figures 3.40 to 3.44. The relative activity per sampling tray was determined on the basis of survey meter readings. The activity in the other collectors was not sufficient to give reliable results by this method, due to the high background existing at Elmer at the time of measurement. All samples were returned for further analysis.

3.5 WEIGHT AND ACTIVITY OF THE FALLOUT SAMPLES

A comparison of the gross fallout collectors (GFC) sample activity with the observed field dose rates for Shots Lacrosse, Zuni, Flathead, and Navajo is shown in Table 3.10. Similar data from Tewa will be available in the final report. The activity per unit area was determined on the basis of the 2.73-ft^2 sampling area of the collector. The H+50 hour dose rate at the station was calculated from the ground readings obtained at the station locations during sample recovery on D+1 or D+2 day.

Table 3.11 shows activity per unit weight for the solids collected in the intermittent and gross fallout collectors. In all cases shown, significant quantities of liquid were collected in the gross fallout

[redacted]

collectors. This liquid, which passed directly through the filter in the collector, contained from 5 to 20 percent as much activity as the solid remaining in the cone of the collector. The YAG-40 figures are based upon the weight and activity of the 0-to-420-micron fraction. The greater-than-420-micron fractions account for less than 2 percent of the total weight.

Activity concentrations for the Flathead gross fallout collector samples were not obtained, because of the manner in which the fallout was deposited in the collecting instruments. Visual examination of the cones from the collectors showed a well defined deposit of mud-like material on the inner surface of the cone. This deposit was located on the upper portion of the southwest side of the cone (Figure 3.45). The diagram indicates that the apparent maximum angle at which this material entered the collector was 26 degrees from the horizontal for the station on Site Able and 31 degrees for the one on Fox. A rough calculation which neglects the perturbation of the air flow by the collector and assumes a

TABLE 3.10 COMPARISON OF GFC SAMPLE ACTIVITIES WITH FIELD DOSE RATE AT VARIOUS STATIONS

Shot	Site	Sample Activity at H 50 hr	Activity Per Unit Area	Dose Rate At Station H+50 hrs	Ratio of Sample Activity To Dose Rate
		10^9 dis/min	10^9 dis/min/ft^2	mr/hr	$\frac{10^7 \text{ dis/min}}{\text{mr/hr}}$
Lacrosse	Wilma	5.663	2.07	91	6.3
Zuni	Charlie	69.27	25.37	1,655	4.2
	Yoke	10.47	3.81	412	2.5
	Bravo	14.88	5.45	360	4.1
	YFNB-29	26.4	9.67		
	YAG-40	10.98	4.02		
	Love	0.226	0.083	11	2.1
Flathead	Able	124.17	45.5	1,285	9.7
	Fox	137.12	50.2	1,720	7.8
Navajo	Charlie 1	9.33	3.42	845	1.10
	Charlie 2	9.78	3.58	845	1.16

density of 1.3 (intermediate between coral and water) indicates that the maximum particle size associated with this "mud" was about 150 microns. The available weather data indicate a 10-knot surface wind from the northeast (azimuth 50 degrees)[1] for Bikini at detonation time. Although none of the material was found in the bottom of the collector, small quantities of loose coral-like particles were observed there. The so-called mud was still wet on D+1 day, but no excess liquid was found in the two collectors in which this slurry was observed.

After the removal of the loose particles from the bottom of the collectors, mud was removed from the inner surface of the cone by scraping while a stream of water was played over the surface. Later surveys indicated that 85 to 90 percent of the activity was removed in this way.

[1]This reported surface wind is subject to further verification since balloon runs gave 20 knots from 90 degrees.

Examination of the intermittent fallout collector trays failed to reveal the presence of the mud. The visible fallout collected in these instruments consisted solely of the loose, coral-like particles. However, after removal of the solid fallout from the dry trays by careful brushing with a camels-hair brush, a large fraction of the total activity remained in the trays, as indicated by survey readings taken before and after brushing. These monitoring data indicated that the activity remaining in the trays after all visible material had been removed varied from tray to tray and was greater, by a factor of ten or more, than the activity removed. Attempts to remove the activity by rinsing with water and with a solution of versene failed to reduce the contamination level by an appreciable amount. Therefore, the total activity collected in the intermittent fallout collector trays for Flathead is not quantitatively known.

The activities per unit area of sampling surface (for both types of material in the gross fallout collectors and for the loose particles only in the intermittent collectors) are compared in Table 3.12 for the Flathead fallout. The physical and chemical characteristics of these samples are described in Section 3.6.3.

TABLE 3.11 ACTIVITY CONCENTRATIONS FOR LACROSSE AND ZUNI SAMPLES

Shot	Site	Distance From Ground Zero	Type of Collector	Weight of Solid Sample	Total Activity of Solid at H+50 hr	Activity Per Gram at H+50 hr
		ft		grams	10^6 dis/min	10^6 dis/min/gm
Lacrosse	Wilma	14,000	GFC	1.4574	56.69	38.9
	Gene	69,000	Canvas	1.1726	99.75	85.0
Zuni	William	35,000	5-min IFC	1.074	22.8	21.0
	William	35,000	30-min IFC	0.8693	15.1	17.0
	Yoke	43,100	5-min IFC	0.4829	13.01	27.0
	Yoke	43,100	GFC	3.531	87.2	25.0
	YFNB-29	55,300	GFC	13.47	248.0	18.0
	YFNB-29	55,300	5-min IFC	0.0276	0.628	23.0
	Bravo	59,800	GFC	3.38	134.5	40.6
	YAG-40	275,000	GFC	0.2858	101.0	354.0

In setting up the stations for Shot Navajo, one intermittent fallout collector on Site Charlie, with 5-minute sampling intervals, was tilted at an angle of 34 degrees to the horizontal and turned to face the expected surface wind direction. Two other 5-minute-interval collectors and a 30-minute-interval collector were left in the usual horizontal position. After the recovery of the Navajo samples, the individual IFC trays were surveyed with an MX-5 survey meter. The tilted collector gave readings as high as 40 mr/hr, as shown in Figure 3.38, while the others read no higher than the 3 or 4 mr/hr background existing in the handling area. These samples were returned for analysis, and complete results will appear in the final report.

Monitoring of the cones in the gross fallout collectors also indicated that a large portion of the activity collected following Navajo adhered to one side of the inner surface of the cone. Since this activity was difficult to remove completely and since the liquid portion of the sample contained a part of the total activity collected, activity per

per unit weight was not calculated.

In order to obtain an estimate of the total activity collected, the surface of the cone was monitored before and after removal of the solid adhering to the walls. The sintered stainless-steel filter was washed with a solution containing versene and hydrochloric acid. The fraction of the total activity remaining in the collector and on the filter was then estimated. After the application of the necessary corrections, the total activity collected was determined by adding together the activity in the solid, that found in the filter, and the activity of the original sample. The sample activities listed in Table 3.10 resulted from these estimates.

Weight and activity measurements resulting from Shot Tewa will appear in the final report.

Weight and activity distribution as a function of particle-size range is shown graphically for one Lacrosse sample and four Zuni samples

TABLE 3.12 ACTIVITY PER UNIT AREA OF COLLECTION SURFACE FOR GFC AND IFC FLATHEAD SAMPLES

Site	Sample Type	Sample Activity at H+50 hr	Sampling Area	Activity Per Unit Area at H+50 hr
		10^9 dis/min	ft^2	10^9 dis/min/ft^2
Able	GFC mud	124.0	2.73	45.4
	GFC loose particles	0.17	2.73	0.06
	GFC total sample	124.17	2.73	45.5
Fox	GFC mud	136.0	2.73	49.8
	GFC loose particles	1.12	2.73	0.41
	GFC total sample	137.12	2.73	50.2
Charlie	IFC loose particles	0.0586	0.125	0.47
	IFC total sample	a	a	a
George	IFC loose particles	0.0514	0.125	0.41
	IFC total sample	a	a	a

[a]See text.

in Figures 3.46 to 3.50. The Lacrosse sample was obtained from the top of a truck canvas, while the Zuni samples were obtained from gross fallout collectors.

3.6 EXAMINATION OF INDIVIDUAL PARTICLES

3.6.1 Shot Lacrosse. The studies were all made on the sample obtained from the canvas top of a truck cab on Site Gene. Figure 3.51 is a photomicrograph of a portion of the 210-to-420-micron size range. Five general types of particles were found: (1) opaque coral; (2) translucent coral; (3) black, sintered particles; (4) transparent crystalline particles; and (5) spherical black particles.

The first two types generally characterize particles of natural coral. Most of the coral particles in the fallout had yellow and black spots on their surfaces. The black, sintered particles were ferromagnetic and gave a positive test for iron with potassium ferrocyanide and potassium thiocyanate. The source of the iron may have been the unusually large amount of pipe extending from and around ground zero. In many cases the interior of these particles was coral. All spherical black particles (Type 5) were black throughout. The transparent crystals gave a positive chloride test with silver nitrate. Phenolphthalein tests on particles of Types 1 and 2 indicated some calcium hydroxide throughout the interiors. However, effervescence with 1 M nitric acid indicated that these particles were predominantly carbonate. Furthermore, the bulk density of the fallout was 2.66 g/cm^3, compared to 2.70 to 2.75 g/cm^3 for natural coral sand.

Table 3.13 lists the frequency of the five types based on examination of 429 particles in the 210-to-420-micron range. Table 3.14 gives

TABLE 3.13 FREQUENCIES OF PARTICLE TYPES IN LACROSSE FALLOUT, GENE CANVAS, 210 to 420μ

Type	Description	Frequency
		pct
1	Opaque coral	74
2	Translucent coral	5
3	Black sintered	12
4	Transparent crystalline	6
5	Spherical	3

the frequency of black particles (Types 3 and 5) as a function of particle size, based on a separate particle count.

No nonradioactive particles were found in this sample. Ninety-five percent of the particles were radioactive throughout. The 5 percent hav-

TABLE 3.14 FREQUENCY OF BLACK PARTICLES IN LACROSSE FALLOUT, GENE CANVAS

Particle Size	Number of Particles Counted	Frequency of Black Particle
μ		pct
44 to 74	549	20.8
74 to 105	590	26.3
105 to 149	154	16.9
149 to 210	146	17.8
210 to 420	671	15.8

ing activity only on their surfaces were of coral. Individual black particles in the 210-to-420-micron range were, on the average, twice as radioactive as white particles, but in the aggregate, they contributed only 25 percent to the total activity of the fraction.

3.6.2 Shot Zuni. Three predominant types of fallout particles were found: (1) opaque coral; (2) translucent coral; and (3) yellow and white spheres. The frequency of occurrence of each type and the radioautographic results are given in Table 3.15. It will be noted that most of the radioactive particles were active throughout. A survey of particles smaller than 149 microns indicated that not more than 1 percent were spherical. Individual spherical particles from the Bravo collector in the 210-to-420-micron range were, on the average, 24 times as active as nonspherical particles and contributed 60 percent of the total activity.

The YAG-40 deck sample was heavily agglomerated in the particle size region above 210 microns. These agglomerates were resistant to mechanical pressure, but the application of water rapidly broke them down into particles of 50 microns or less. The resulting solution gave a strong test for chloride ion.

Particles of Types 1 and 2 appeared to be homogeneous mixtures of $CaCO_3$ and CaO or $Ca(OH)_2$. They were generally free of the yellow and brown spots observed after Shot Lacrosse. Type 1 particles gave a positive test for chloride ion.

The spheres appeared to be CaO or $Ca(OH)_2$, with a surface coating of $CaCO_3$. After the samples had been stored for several weeks, spheres could no longer be found. The spheres that had been sectioned swelled and erupted out of the plastic mounts after several weeks, in some cases cracking the plastic. In this form they were a loose mass of tiny crystals.

TABLE 3.15 FREQUENCIES OF PARTICLE TYPES IN ZUNI FALLOUT

Sample Location and Size Range	Particle Type	Frequency of Type	Frequency of Hot Particles	Frequency of Volume Activity Among Hot Particles	Frequencies of Surface Activity Among Hot Particles	Number of Particles Counted
μ		pct	pct	pct	pct	
Yoke 149 to 210	Opaque	46	38	100	0	226
	Translucent	53	42	100	0	
	Spherical	1	100	100	0	
Yoke 210 to 420	Opaque	60	56	94	6	460
	Translucent	39	50	100	0	
	Spherical	1	100	100	0	
Yoke 420 to 840	Opaque	63	58	14	86	345
	Translucent	27	65	55	45	
	Spherical	10	90	85	15	
Bravo 149 to 210	Opaque	53	95	95	5	565
	Translucent	45	60	100	0	
	Spherical	2	100	100	0	
Bravo 210 to 420	Opaque	63	73	87	13	1199
	Translucent	31	37	97	3	
	Spherical	6	100	98	2	
Bravo 420 to 840	Opaque	77	88	2	98	606
	Translucent	17	34	80	20	
	Spherical	6	95	100	0	
Charlie 149 to 210	Opaque	75	82	100	0	375
	Translucent	24	37	100	0	
	Spherical	1	100	100	0	
Charlie 210 to 420	Opaque	58	73	72	28	155
	Translucent	37	61	98	2	
	Spherical	5	100	85	15	
Charlie 420 to 840	Opaque	85	83	13	87	136
	Translucent	12	55	100	0	
	Spherical	3	100	100	0	
YAG-40 149 to 210	Opaque	46	100	100	0	612
	Translucent	36	100	100	0	
	Spherical	18	100	100	0	
YAG-40 210 to 420	Opaque	63	100	100	0	327
	Translucent	28	100	100	0	
	Spherical	9	100	100	0	

[redacted]

[redacted]

TABLE 3.16 FRACTIONATION IN LACROSSE FALLOUT

Sample	Particle Size
	μ
Wilma Ground	0- 44
	44- 74
	74-105
	105-149
	149-210
	210-420
Gene Ground	0- 5
	5- 14
	10- 22
	16- 32
	26- 40
	40- 50
	44- 74
	74-105
	105-149
	149-210
	210-420
Gene Canvas	0- 44
	44- 74
	74-105
	105-149
	149-210
	210-420
	420-840
	Total Solid
LASL Cloud Sample	

[a]This error term is a measure of the internal consistency of the analysis procedure as related to four aliquots.

(b) (3)

TABLE 3.17 ACTIVITY CONCENTRATIONS IN LACROSSE FALLOUT

Sample	Particle Size
	μ
Gene Canvas	0- 44
	44- 74
	74-105
	105-149
	149-210
	210-420
	420-840
	Total Solid

[redacted] - [redacted]

A few metallic-looking flakes, which gave a strong test for iron, were observed.

It should be noted that the YAG-40 deck sample was exposed to a large volume of rain before and after cessation of fallout and, presumably, to significant salt spray.

The bulk density of the sample of fallout from the Bravo collector was 2.17 g/cm^3.

3.6.3 Shot Flathead. Three types of fallout were found: (1) brown mud; (2) discrete, solid particles; and (3) liquid. The brown mud accounted for more than 99 percent of the total activity in the Able and Fox gross fallout collectors. Very little liquid was collected. The pattern of the mud on the walls of the collectors has been described in Section 3.5. The mud consisted of fine coral particles, sodium chloride, and a large quantity of Fe_2O_3, suspended in water droplets about 1 or 2 mm in diameter. This material was hard to remove after it had dried on the walls of the collectors. Laboratory equipment used in handling this material was also difficult to decontaminate, and recovery personnel had extreme difficulty decontaminating their hands and shoes.

The discrete, solid particles exhibited a wide variety of types, but $CaCO_3$ predominated. As was pointed out above, these particles did not contribute significantly to the activity.

3.6.4 Shot Navajo. Particles from the Charlie gross fallout collector were examined under the microscope. At least 80 or 90 percent of them were fine crystals of NaCl which were hygroscopic and tended to agglomerate. Most of the remaining particles were $CaCO_3$. There were some small pieces of shiny metal, probably aluminum scraped from the collector during removal of the sample. No iron was detected. Since NaCl was predominant, further study of the particles was not considered worthwhile.

3.7 RADIOCHEMISTRY

3.7.1 Shot Lacrosse. Only the Wilma total fallout collector was within the fallout area, and it collected only a small sample. However, a sample (designated "Wilma ground") was scooped from the ground at this location at approximately H+10 hours. Late on D+1 four samples were obtained from Gene. These consisted of three samples from the ground, which were combined and designated "Gene ground," and a sample from the canvas top of a truck cab (designated "Gene canvas").

(b) (3)

(b) (3)

The particle-size ranges listed in the tables should be regarded as rough approximations. Microscopic particle-size measurements were not available for this report. Experience with fallout samples from past operations has indicated that the average size usually corresponds to the upper limit of the sieve range or calibrated Roller analyzer range. For standard sieves, the averages have sometimes been even higher. Measured sizes will be included in the final report.

Standard deviation has been used as the precision index for all radiochemical data in this report.

R-values[1] between Sr^{89}, Mo^{99}, I^{131}, Ba^{140}, and Ce^{144} will be presented in the final report.

3.7.2 Shot Zuni. The radiochemical fractionation data for Shot Zuni are presented in Table 3.18. The sample designated "YAG-40 Deck" was scooped from three locations on top of the forward deckhouse of the YAG-40 near the foot of the kingpost. The cloud sample was prepared by Program 21 by dry-ashing filter paper. The figures in Table 3.18 were calculated in the same manner as those in Table 3.16. The self-absorption errors in the percentage contributions were considerably less significant, because the weights of the counting samples were much smaller than for Shot Lacrosse.

(b) (3)

(b) (3)

TABLE 3.18 RADIOCHEMICAL FRACTIONATION IN ZUNI FALLOUT

Sample	Particle Size
	μ
Cloud	
YFNB-29	Total Solid
	Liquid Supernate
	Liquid Suspension
Bravo GFC	
	Liquid
	0 - 5
	5 - 44
	44 - 74
	74 - 105
	105 - 149
	149 - 210
	210 - 420
	420 - 840
	840
	Weighted Average[b]
YAG-40 Deck	0 - 5
	5 - 14
	10 - 22
	16 - 32
	26 - 40
	44 - 74
	74 - 105
	105 - 149
	149 - 210
	210 - 420
	420 - 840
	840
	Weighted Average[b]

(b) (3)

[a] Figures with a standard deviation greater than 25 percent.
[b] The weighted averages were calculated by weighting the specific activities (disintegrations or counts per minute per unit weight) by the mass of each fraction collected and then taking the appropriate ratios.

(b) (3)

When the YFNB-29 liquid sample was received in the laboratory, it contained a suspension of $CaCO_3$. The two phases were separated to give the YFNB-29 liquid suspension and YFNB-29 liquid supernate shown in Table 3.18. The supernate was basic to phenolphthalein and gave positive tests for Na^+, Ca^{++}, Cl^-, and SO_4^{--}. The large variation within the YFNB-29 sample is discussed in Section 4.6.

Analyses for Ca^{45}, Sr^{89}, Sr^{90}, I^{131}, Sb^{122}, Sb^{124}, Ba^{140}, Ce^{144}, Ta^{182}, and Ta^{183} are in progress at the Army Chemical Center.

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(b) (3)

The present values are estimated to be accurate within 25 percent.

3.7.3 Shot Flathead. Radiochemical results from this shot are given in Tables 3.20 and 3.21.

(b) (3)

The analyses reported show excellent agreement between the Fox and Able mud.

3.8 BASE-SURGE RESULTS

Base-surge detectors were installed at one or more stations for Shots Zuni, Flathead, Navajo, and Tewa. During Shot Zuni, the station on Oboe failed to receive the H-1 minute signal, and the operation of the stations on Fox and George for Shot Navajo was interrupted by water waves. The only complete record obtained was from the instrument on Fox at a distance of 11,960 feet from the Flathead ground zero. The record did not show any indication of the presence of base surge at this station.

(b) (3)

TABLE 3.20 RELATIVE FRACTIONATION OF NUCLIDES IN FLATHEAD FALLOUT

Sample
Charlie IFC
hr
0 - 1
1 - 1.5
1.5- 2
2 - 2.5
2.5- 4
4 - 6
6 - 7.5
7.5- 9
9 -10.5
Weighted Average
Fox IFC
min
0 - 1
1 - 2
3 - 5
5 - 7
7 - 9
9 -14
14 -17
17 -19
20 -21
Weighted Average
Fox GFC Mud
Able GFC Mud
Fox GFC Particles
George GFC Liquid

(b) (3)

(b) (3)

TABLE 3.21 CONTRIBUTIONS OF NUCLIDES TO FLATHEAD GROSS ACTIVITY

Sample
Charlie IFC
hr
0 - 1
1 - 1.5
1.5- 2
2 - 2.5
2.5- 4
4 - 6
6 - 7.5
7.5- 9
9 -10.5
Weighted Average
Fox IFC
min
0 - 1
1 - 2
3 - 5
5 - 7
7 - 9
9 -14
14 -17
17 -19
20 -21
Weighted Average
Fox GFC Mud
Able GFC Mud
Fox GFC Particles

(b) (3)

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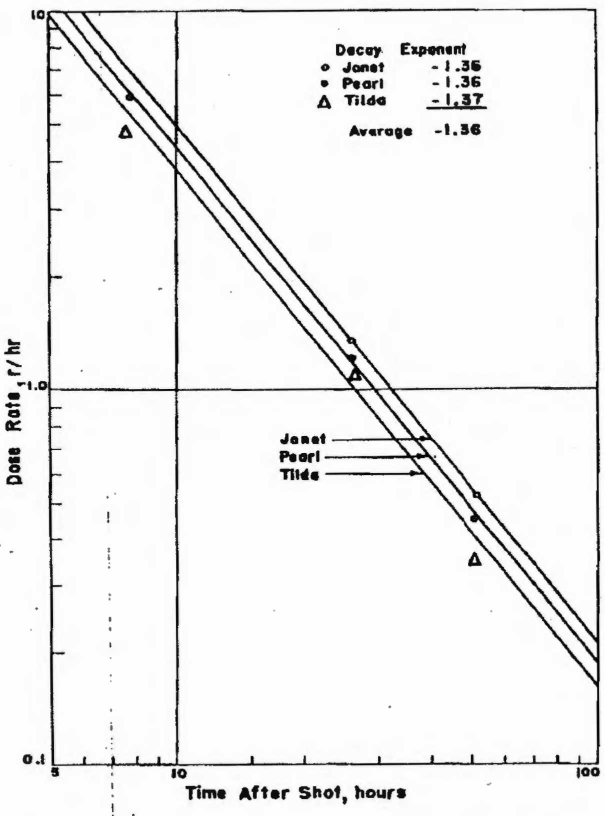

Figure 3.1 Field gamma-decay curve from Lacrosse aerial survey.

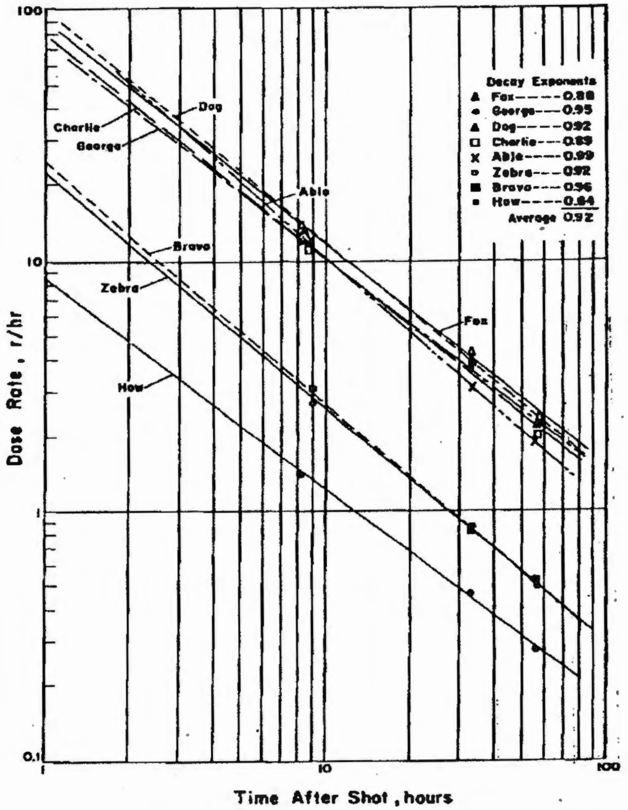

Figure 3.2 Field gamma-decay curve from Zuni aerial survey.

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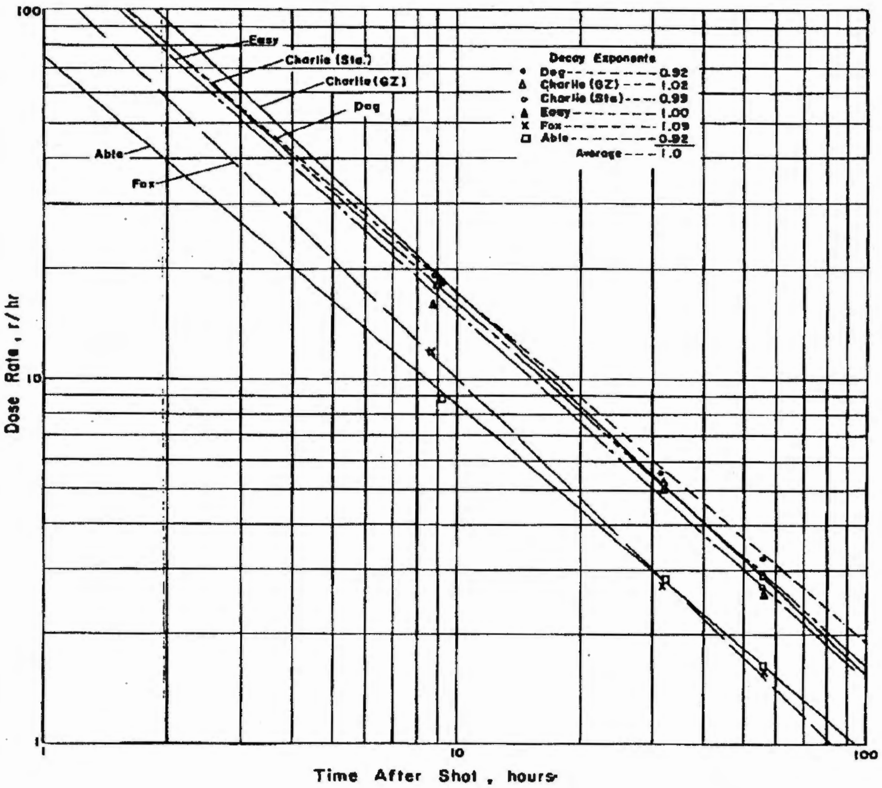

Figure 3.3 Field gamma-decay curve from Flathead aerial survey.

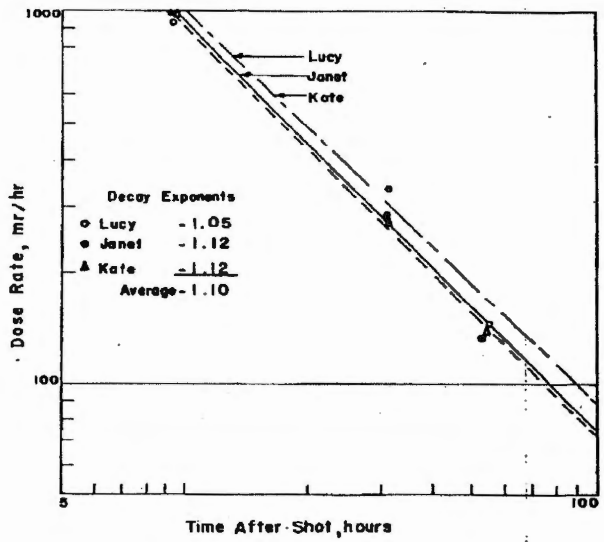

Figure 3.4 Field gamma-decay curve from Mohawk aerial survey.

[redacted]

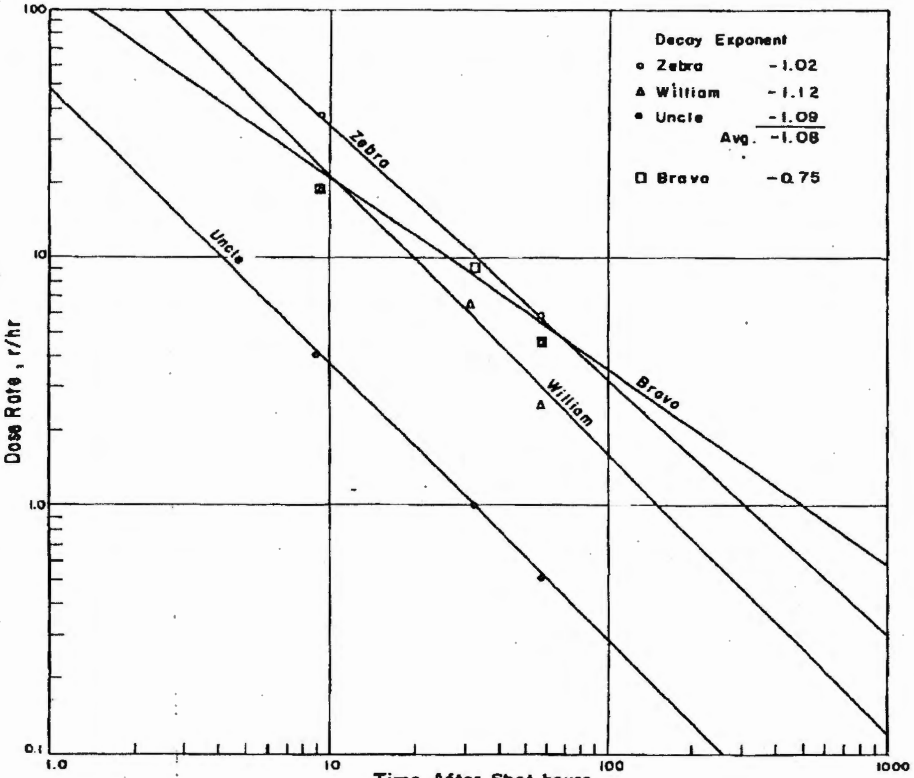

Figure 3.5 Field gamma-decay curve from Tewa aerial survey.

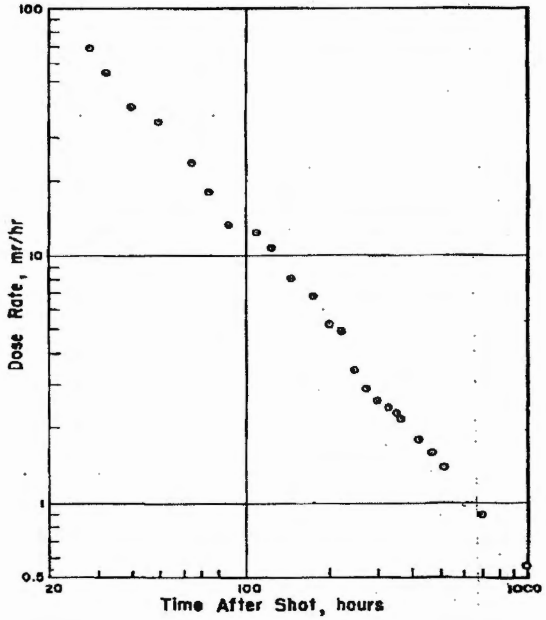

Figure 3.6 Laboratory gamma-dose-rate decay curve of a solid sample from Lacrosse.

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[redacted] - [redacted]

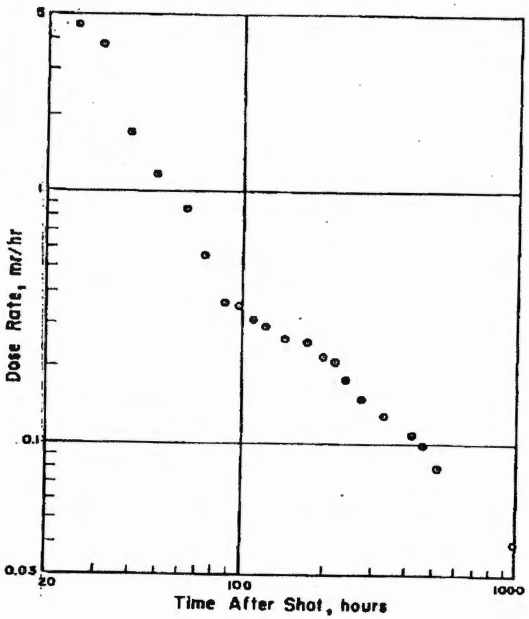

Figure 3.7 Laboratory gamma-dose-rate-decay curve of a liquid sample from Shot Lacrosse.

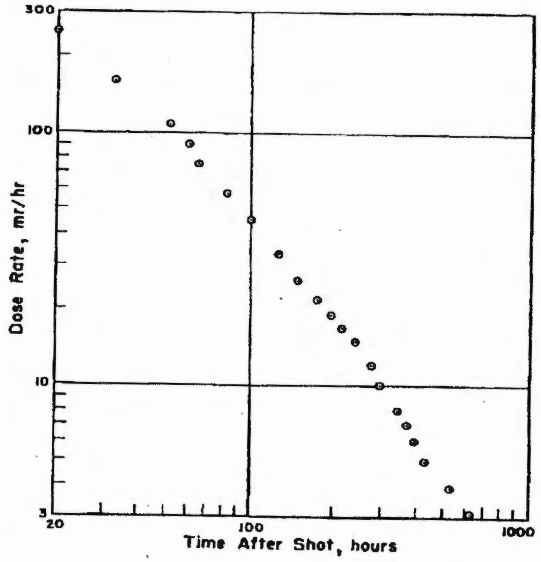

Figure 3.8 Laboratory gamma-dose-rate-decay curve of a sample from Shot Zuni.

[redacted]

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[redacted]

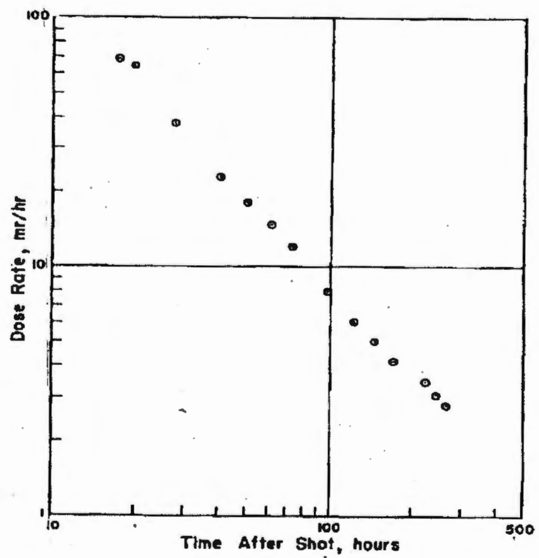

Figure 3.9 Laboratory gamma dose-rate-decay curve of a sample from Shot Flathead.

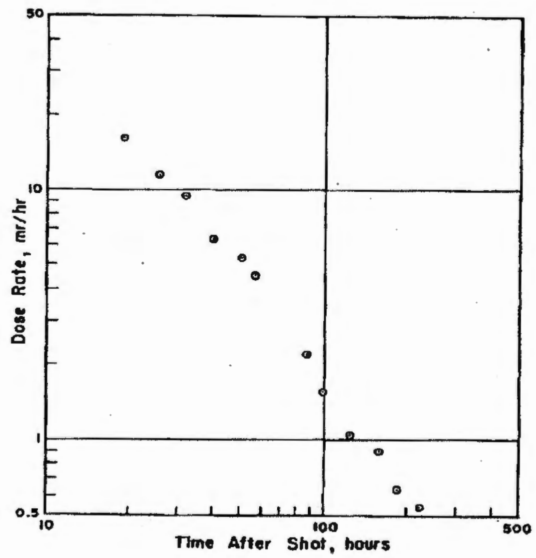

Figure 3.10 Laboratory gamma dose-rate-decay curve of a sample from Shot Navajo.

[redacted]

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[redacted]

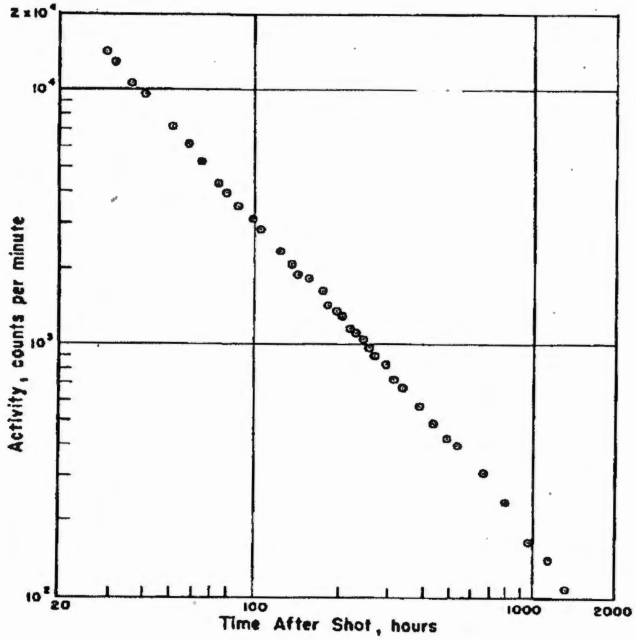

Figure 3.11 Laboratory beta decay curve of a solid sample from Shot Lacrosse.

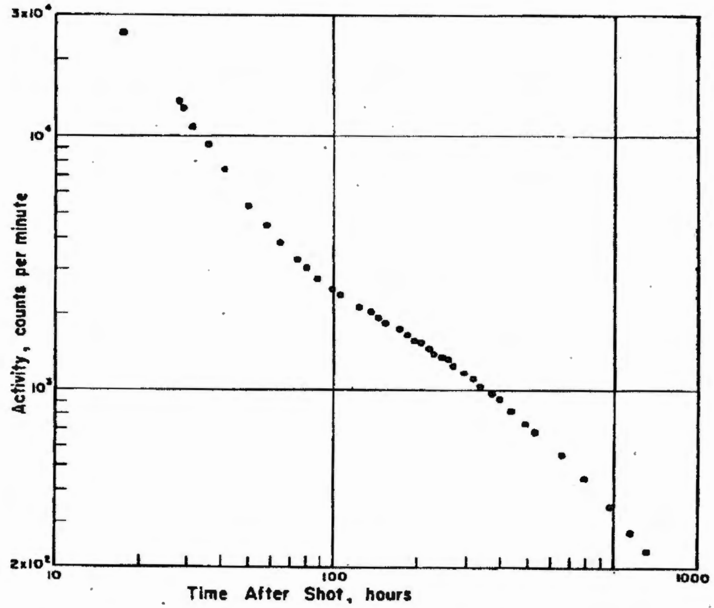

Figure 3.12 Laboratory beta decay curve of a liquid sample from Shot Lacrosse.

[redacted]

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[redacted]

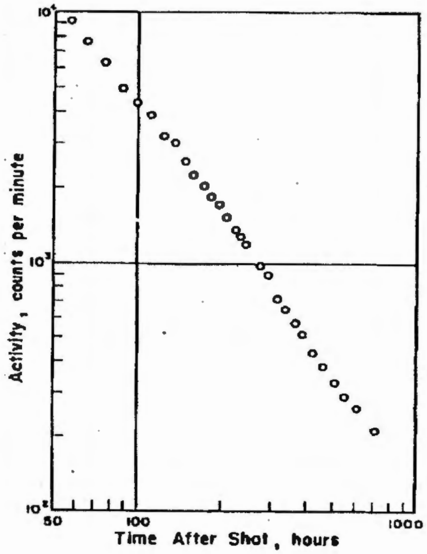

Figure 3.13 Laboratory beta decay curve of a solid sample from Shot Zuni.

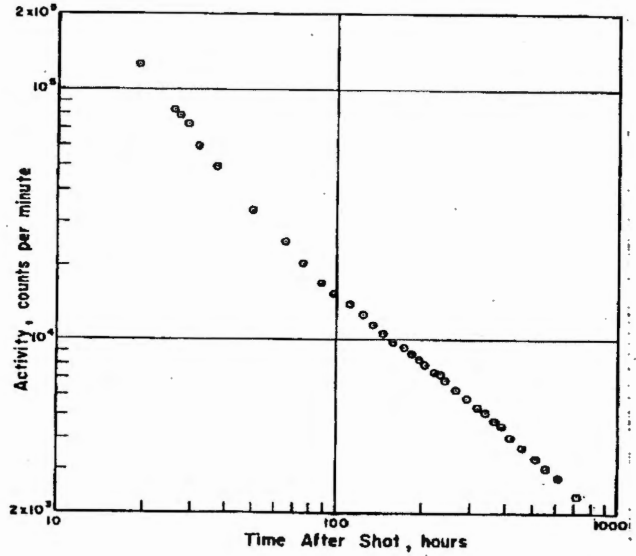

Figure 3.14 Laboratory beta decay curve of a liquid sample from Shot Zuni.

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[redacted] - [redacted]

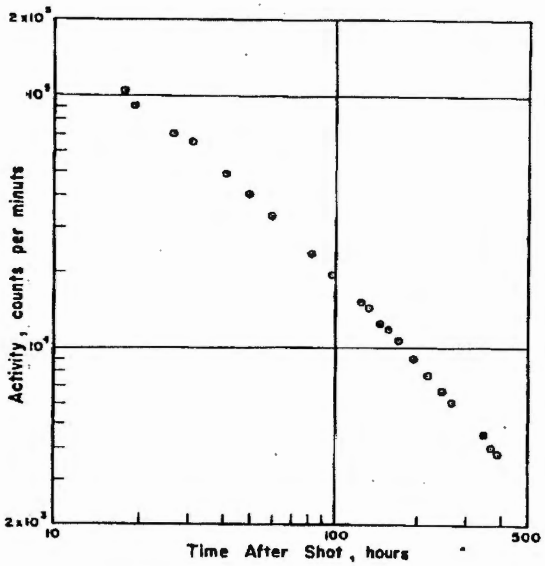

Figure 3.15 Laboratory beta decay curve of a liquid-and-solid (mud) sample from Shot Flathead.

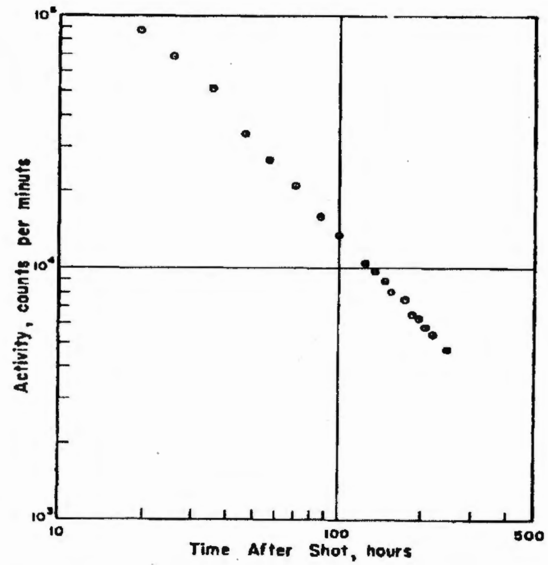

Figure 3.16 Laboratory beta decay curve of a solid sample from Shot Navajo.

[redacted]

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[redacted]

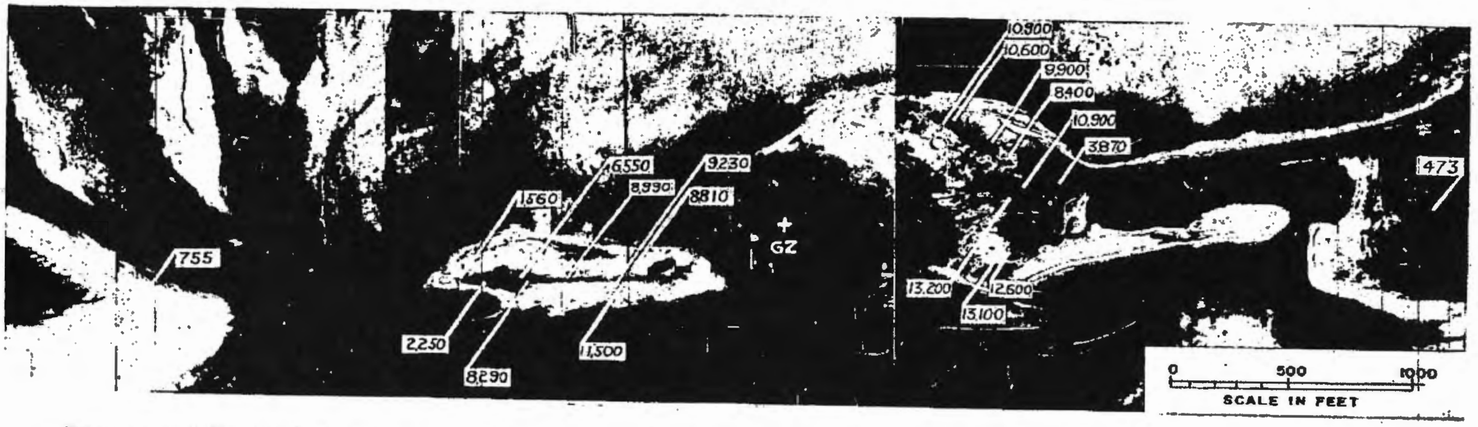

Figure 3.17 Aerial survey readings at 3 feet in the vicinity of the Mohawk crater, corrected to H+1 hour in r/hr.

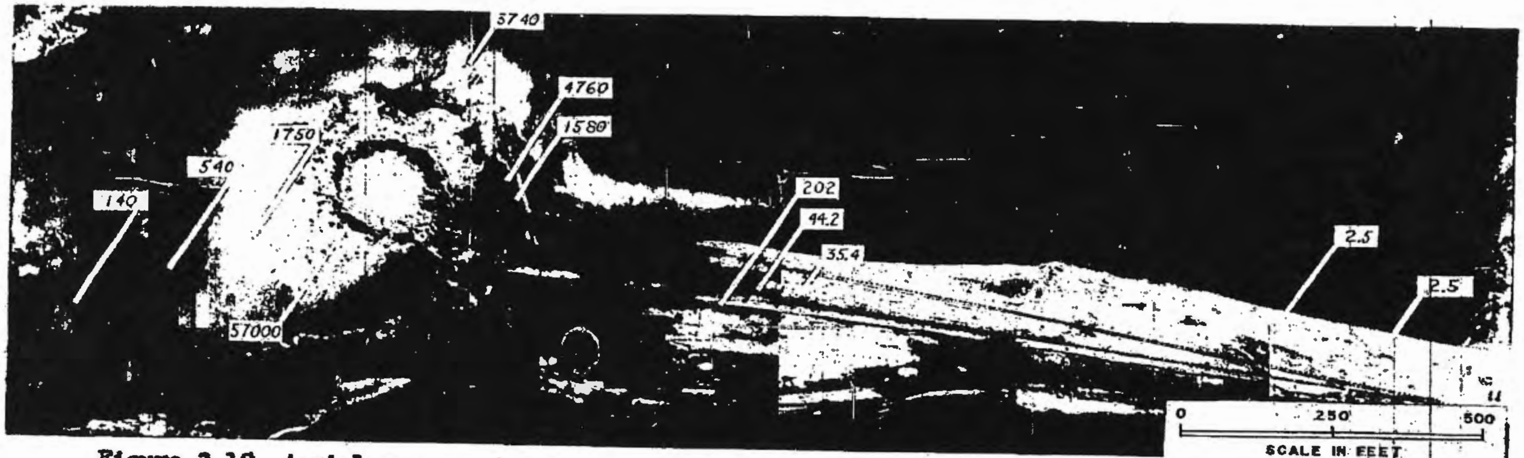

Figure 3.18 Aerial survey at 3 feet on Site Yvonne after Shot Lacrosse, corrected to H+1 hour in r/hr.

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[redacted]

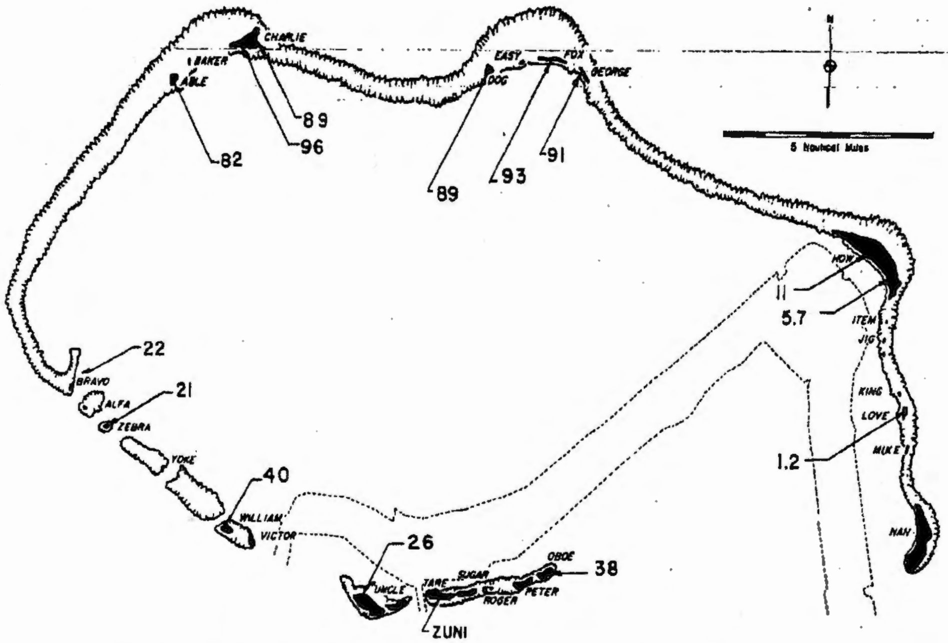

Figure 3.19 Zuni aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

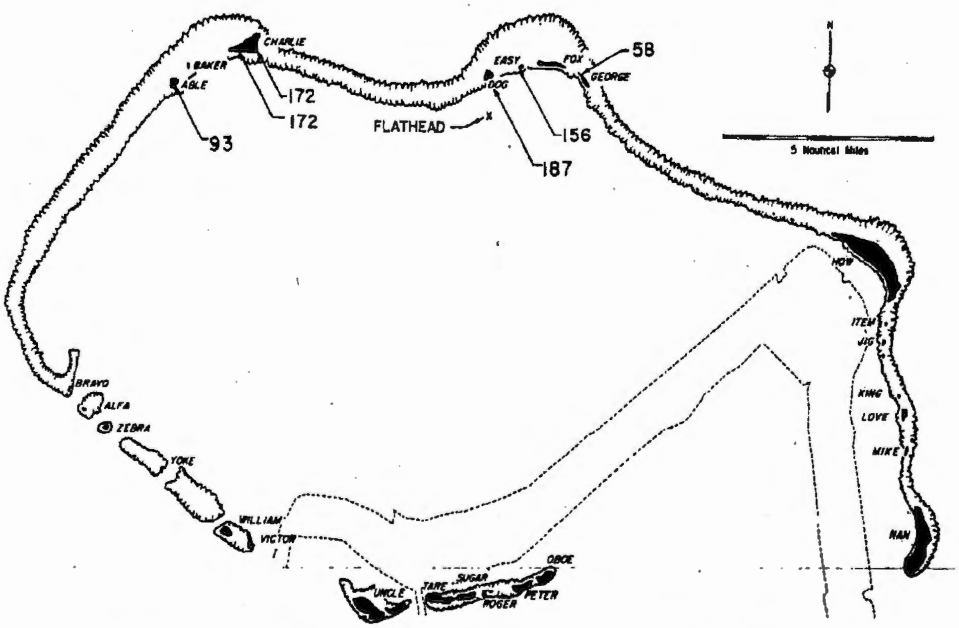

Figure 3.20 Flathead aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

[redacted] [redacted]

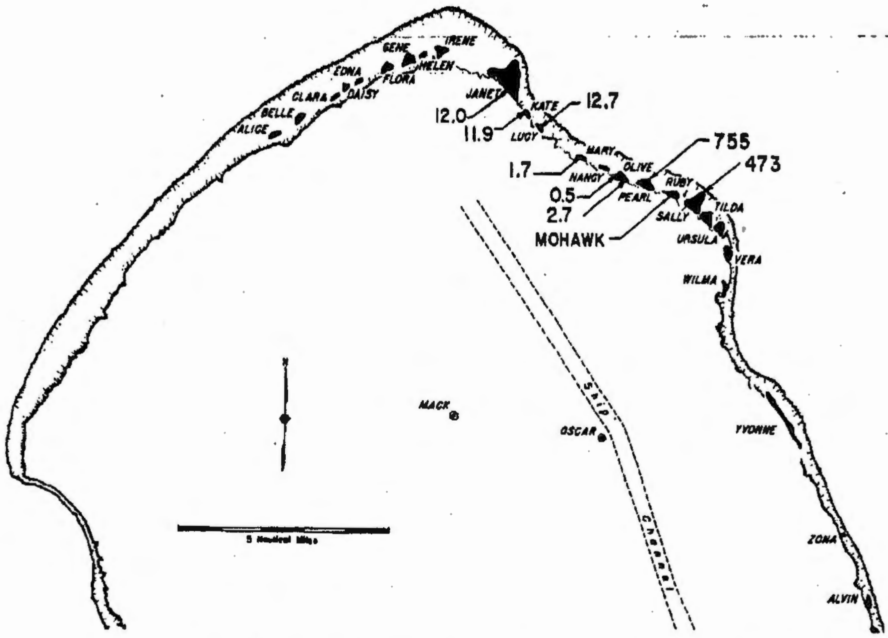

Figure 3.21 Mohawk aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

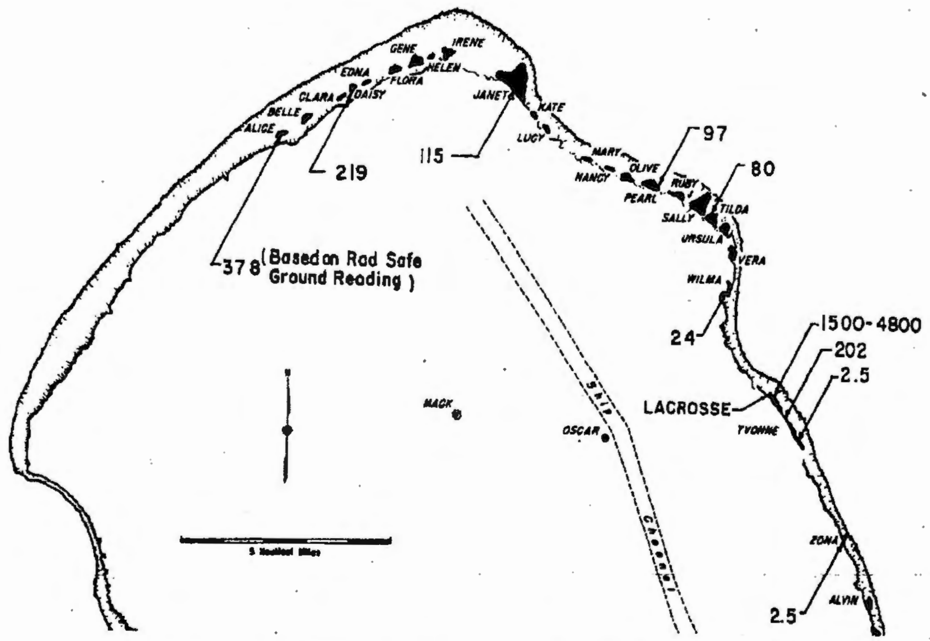

Figure 3.22 Lacrosse aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

[redacted]

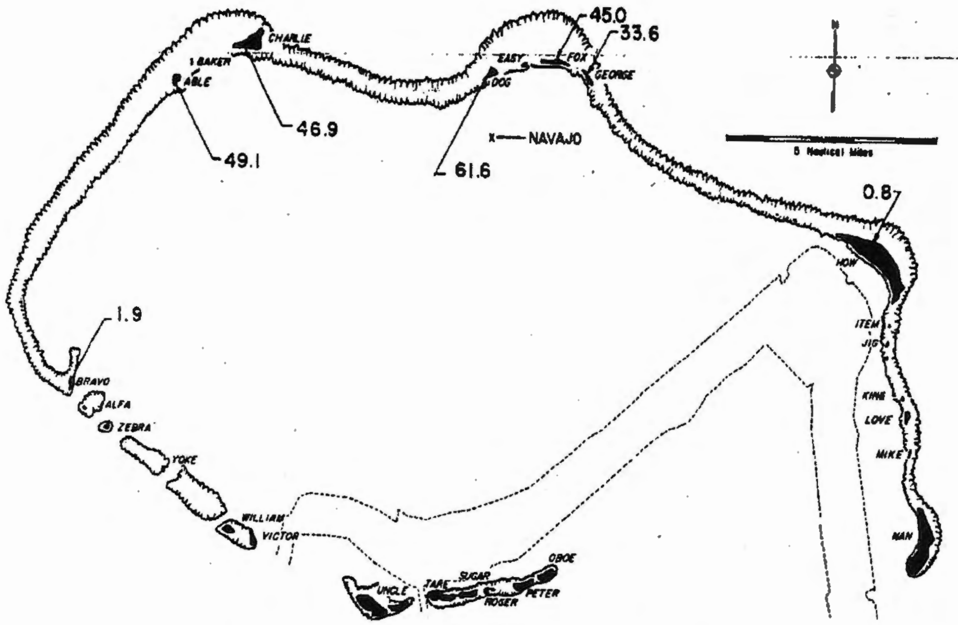

Figure 3.23 Navajo aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

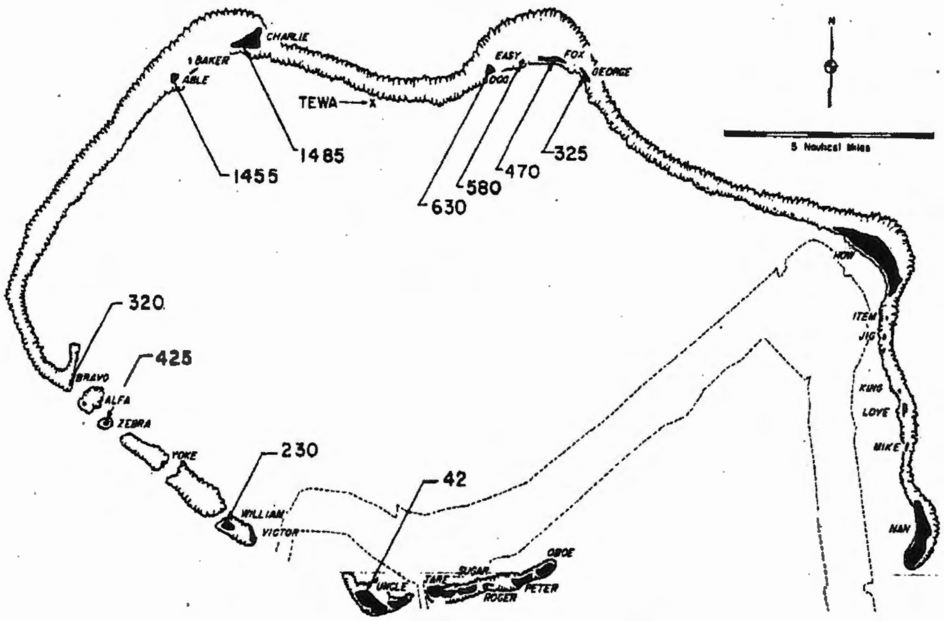

Figure 3.24 Tewa aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

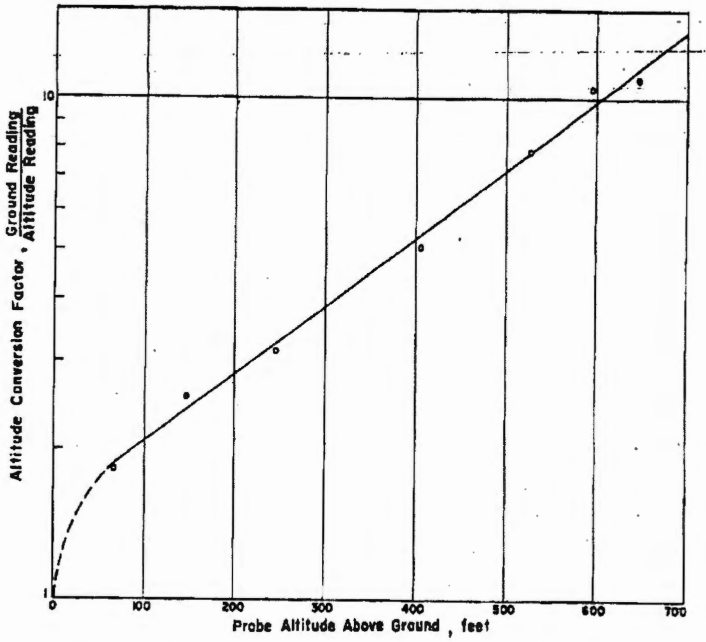

Figure 3.25 Zuni altitude-conversion factors. (Data taken at H+54 hr).

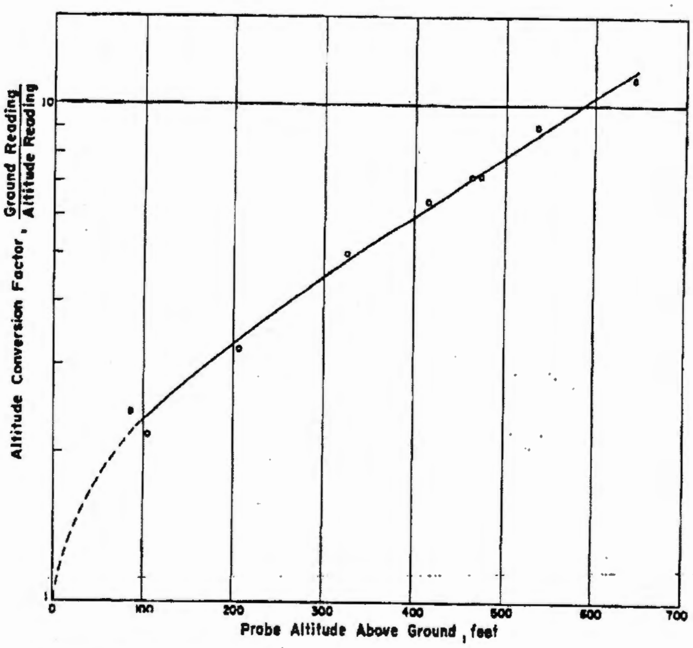

Figure 3.26 Flathead altitude-conversion factors. (Data taken at H+9 hr).

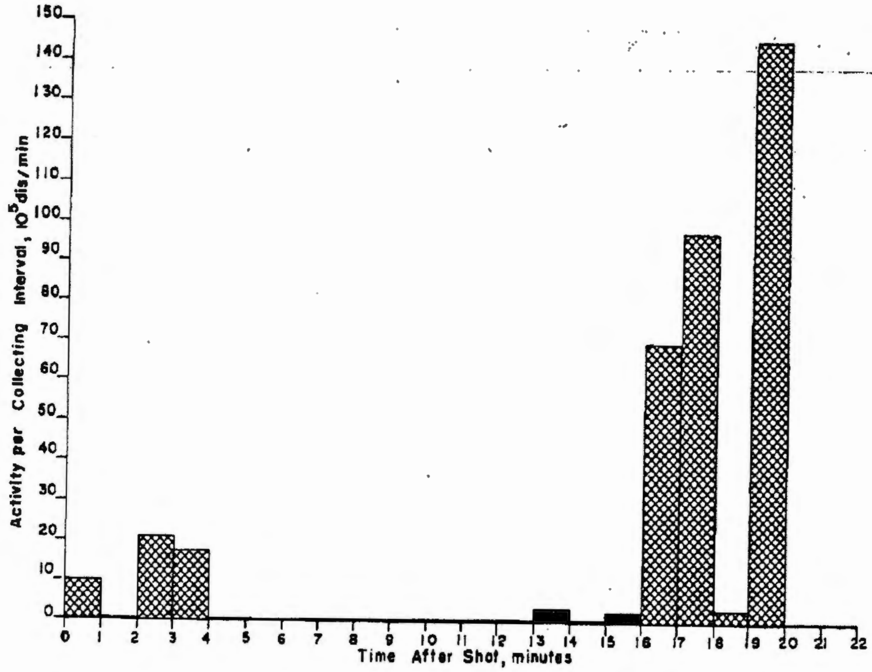

Figure 3.27 Activity collected by 1-minute-interval collector at Site Oboe for Shot Zuni.

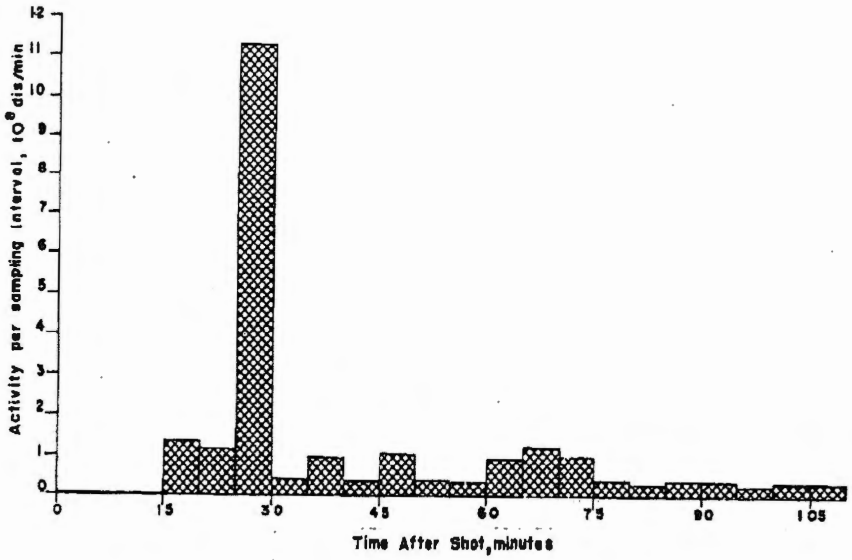

Figure 3.28 Activity collected by 5-minute-interval collector at Site William for Shot Zuni.

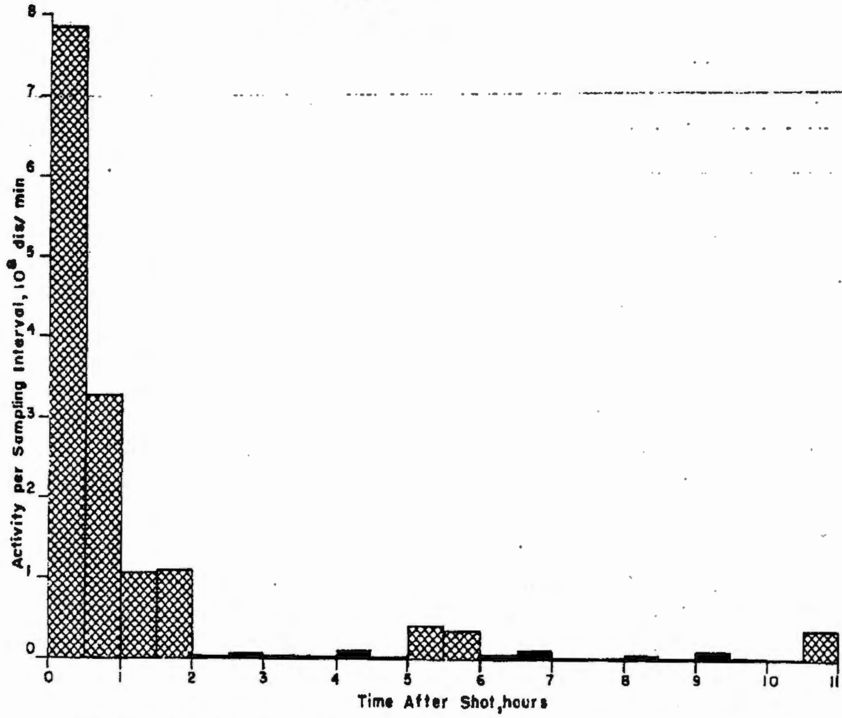

Figure 3.29 Activity collected by 30-minute-interval collector at Site William for Shot Zuni.

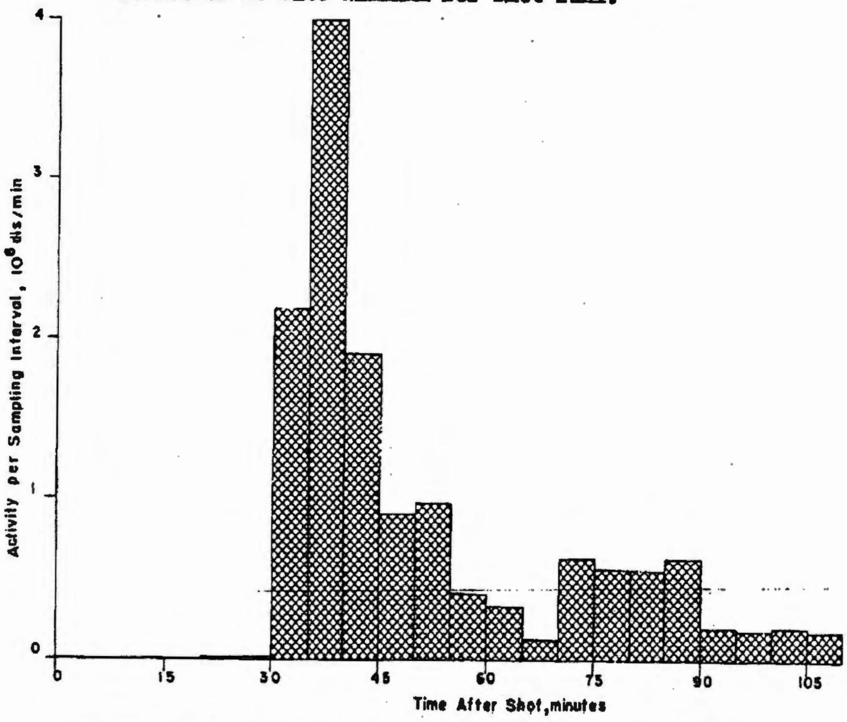

Figure 3.30 Activity collected by 5-minute-interval collector at Site Yoke for Shot Zuni.

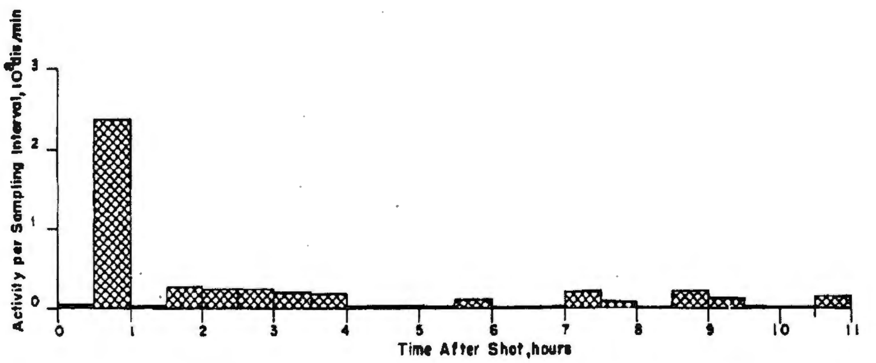

Figure 3.31 Activity collected by 30-minute-interval collector at Site Yoke for Shot Zuni.

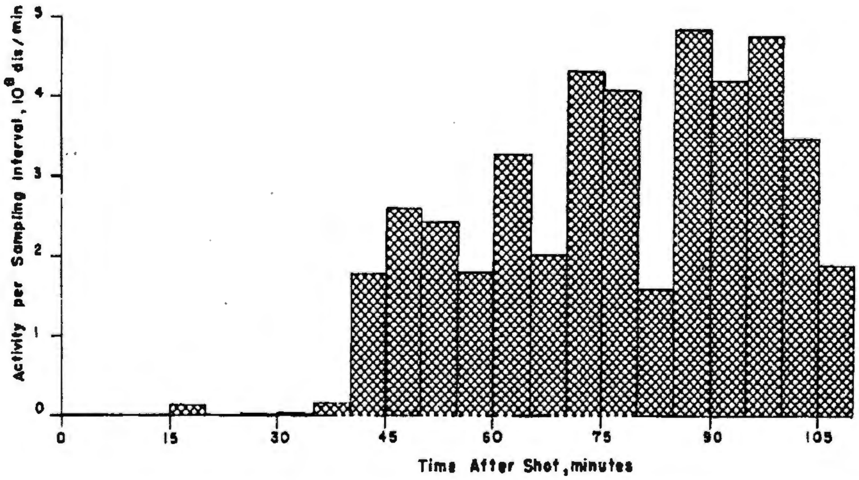

Figure 3.32 Activity collected by 5-minute-interval collector at Site Charlie for Shot Zuni.

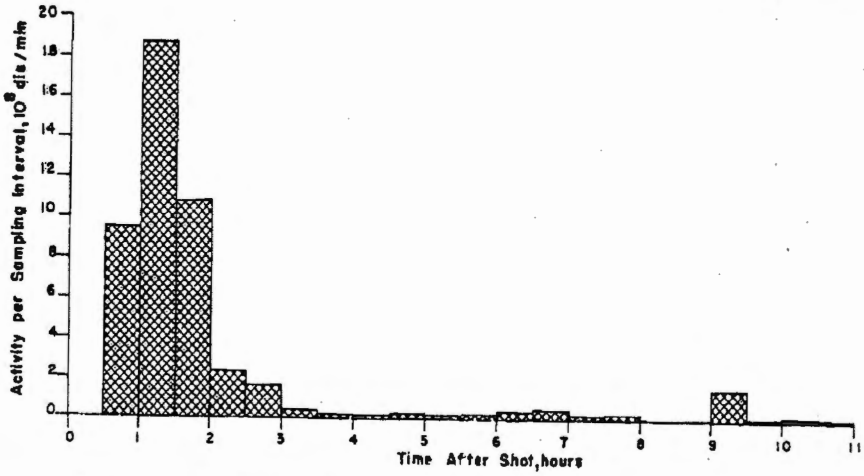

Figure 3.33 Activity collected by 30-minute-interval collector at Site Charlie for Shot Zuni.

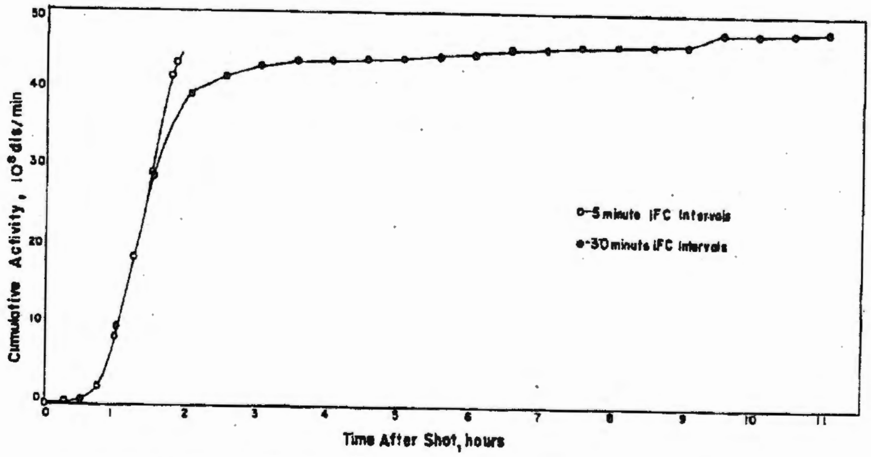

Figure 3.34 Arrival of activity at Site Charlie for Shot Zuni.

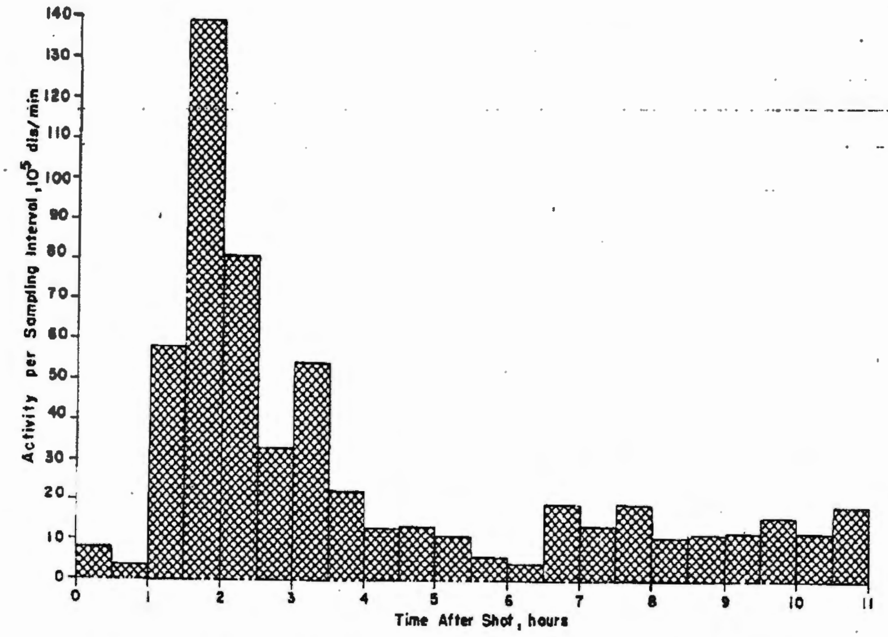

Figure 3.35 Activity collected by 30-minute-interval collector at Site Charlie for Shot Flathead.

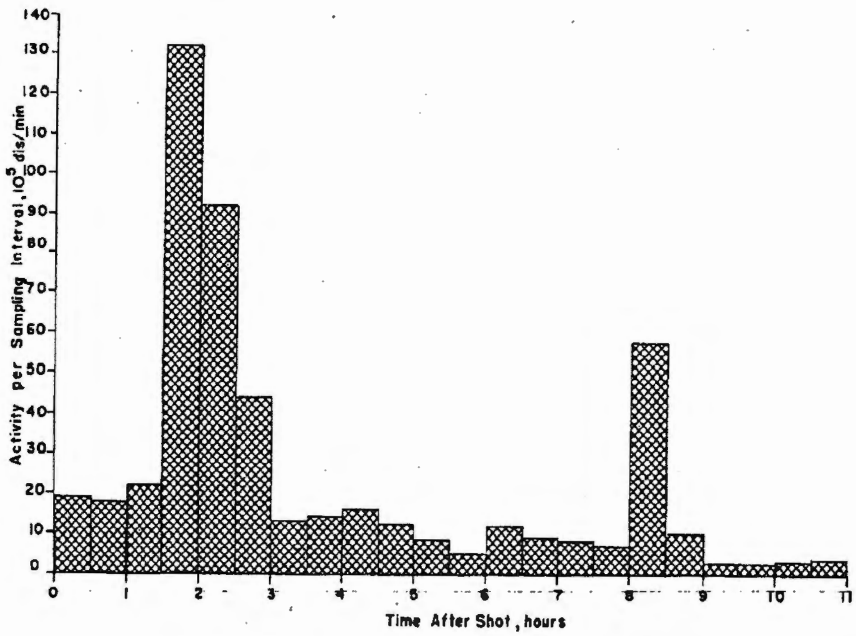

Figure 3.36 Activity collected by 30-minute-interval collector at Site George for Shot Flathead.

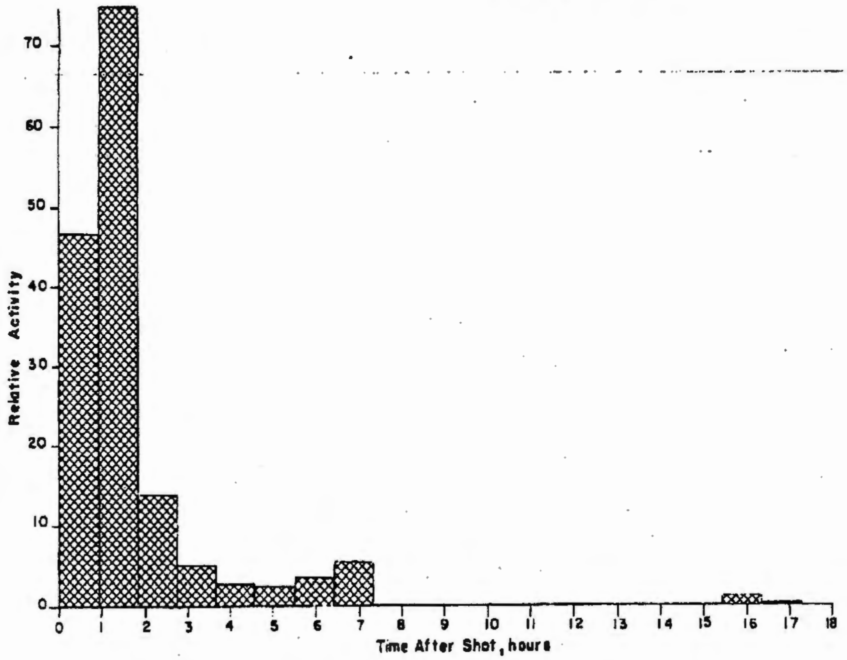

Figure 3.37 Survey readings of tape fallout monitor record from Site George for Shot Flathead.

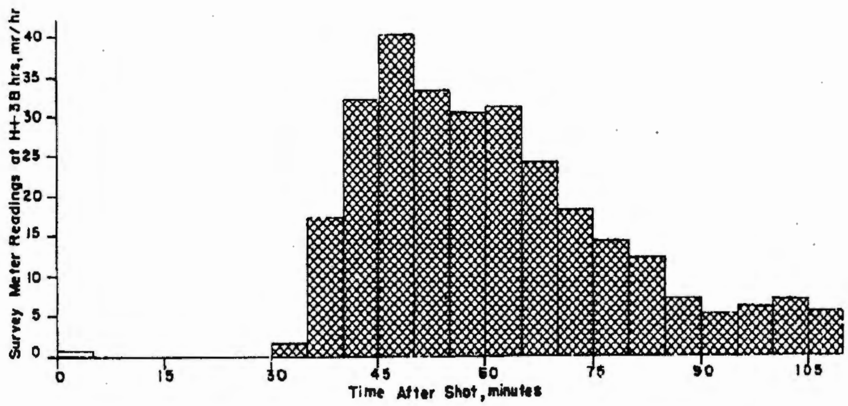

Figure 3.38 Activity collected by 5-minute-interval collector at Site Charlie for Shot Navajo.

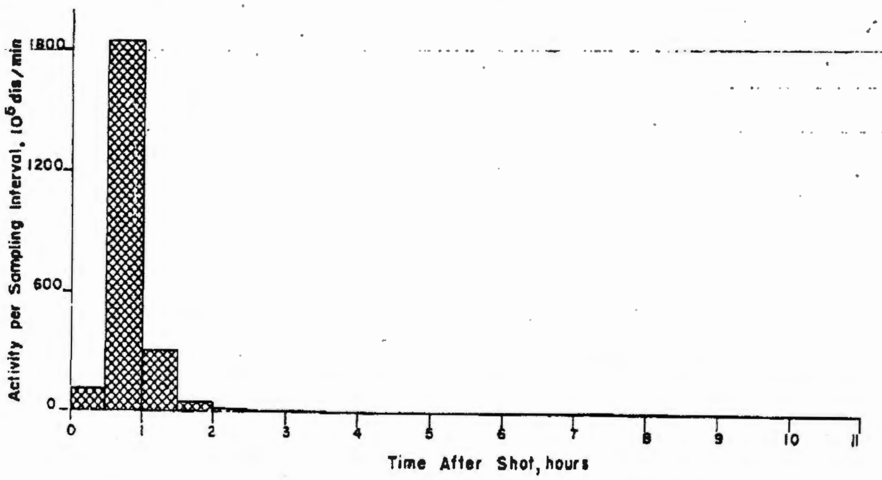

Figure 3.39 Activity collected by 30-minute-interval collector at Site Charlie for Shot Navajo.

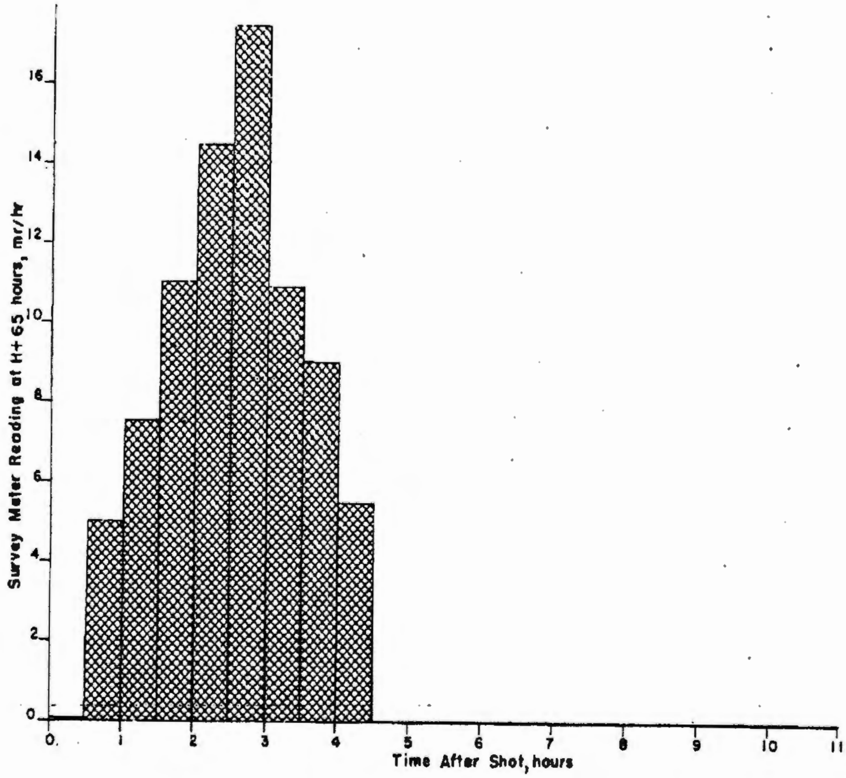

Figure 3.40 Activity collected by 30-minute-interval collector at Site George for Shot Tewa.

[redacted] [redacted]

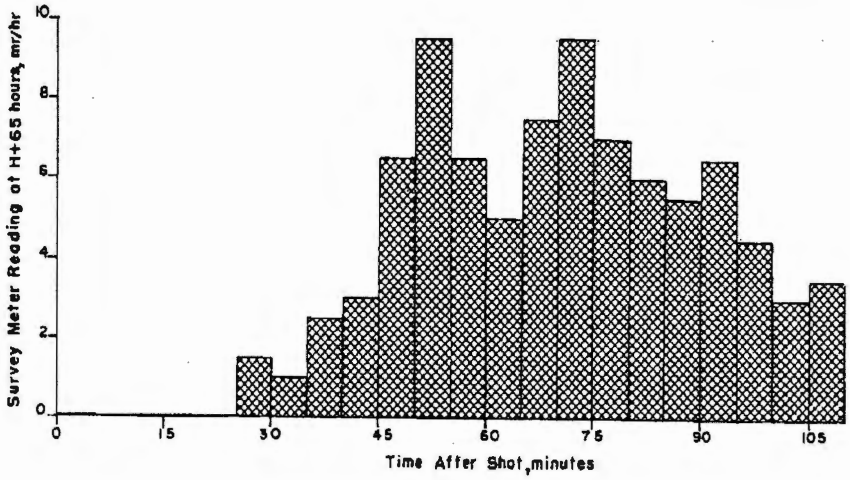

Figure 3.41 Activity collected by 5-minute-interval collector on YFNB-29 for Shot Tewa.

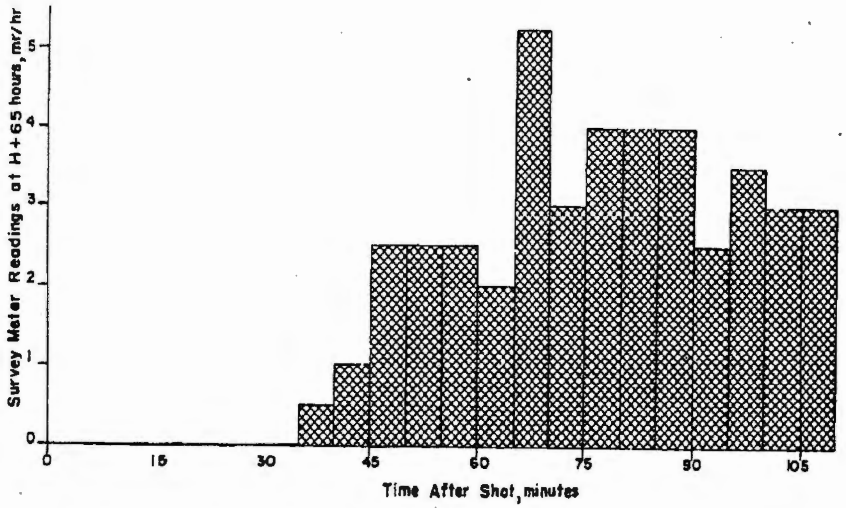

Figure 3.42 Activity collected by 5-minute-interval collector at Site Yoke for Shot Tewa.

[redacted]

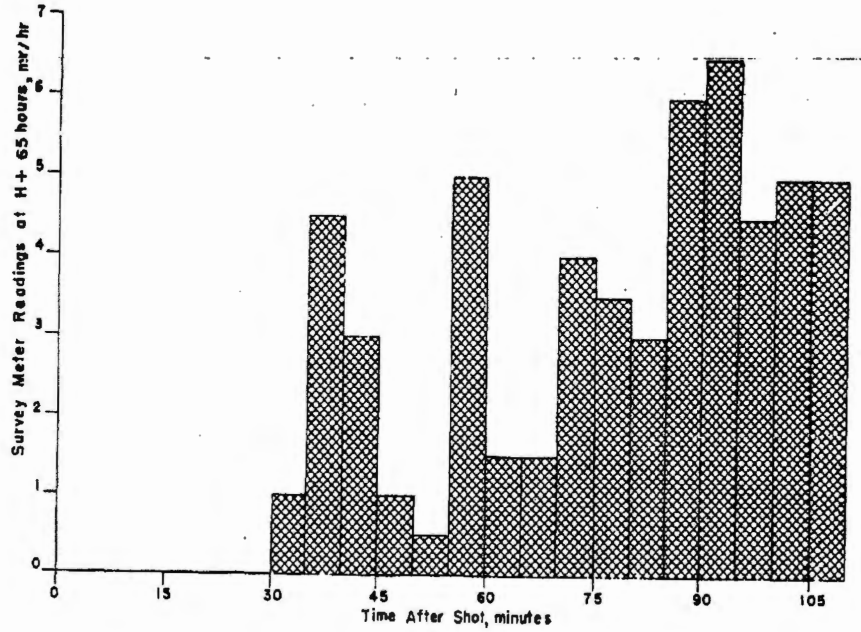

Figure 3.43 Activity collected by 5-minute-interval collector at Site William for Shot Tewa.

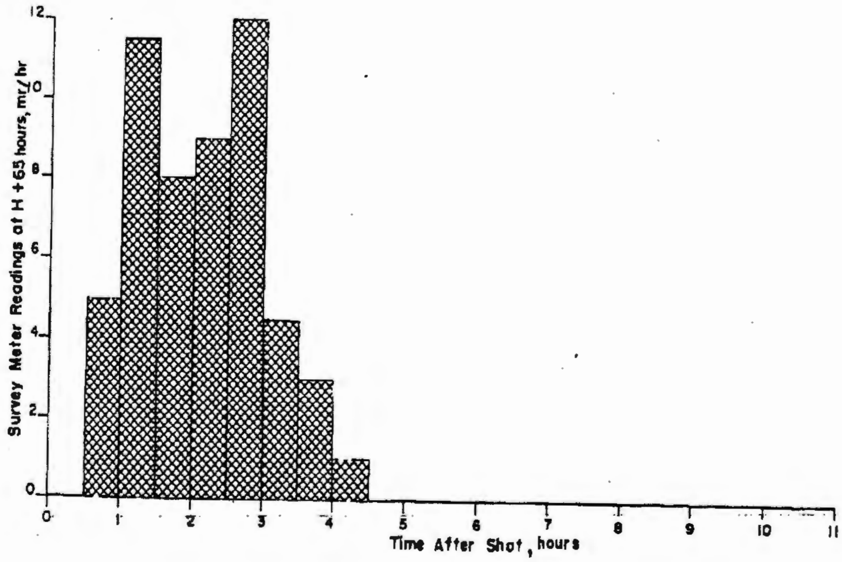

Figure 3.44 Activity collected by 30-minute-interval collector at Site William for Shot Tewa.

[redacted]

[redacted]

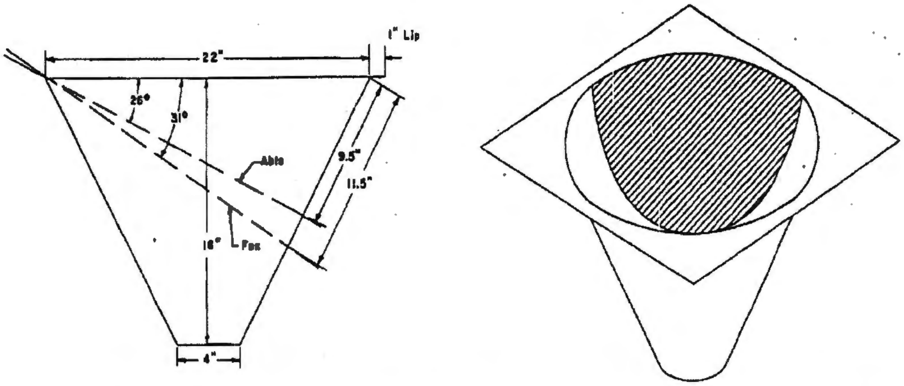

Figure 3.45 Pattern formed in gross-fallout collector by Flathead fallout, and maximum angle at which it entered.

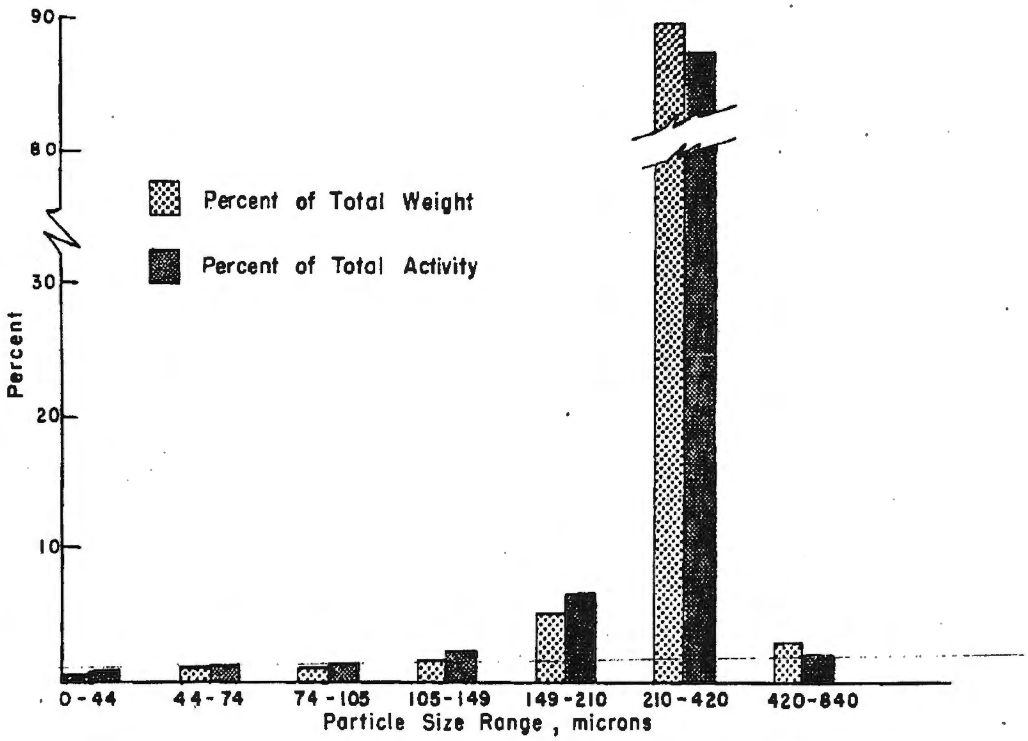

Figure 3.46 Weight and activity distribution for Gene Sample, Shot Lacrosse, 69,000 feet from ground zero.

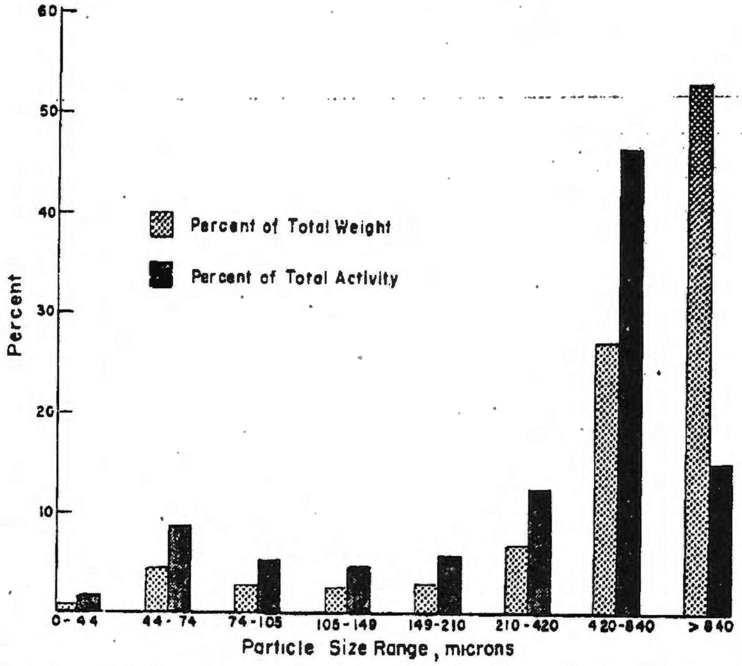

Figure 3.47 Weight and activity distribution for Yoke sample, Shot Zuni, 43,100 feet from ground zero.

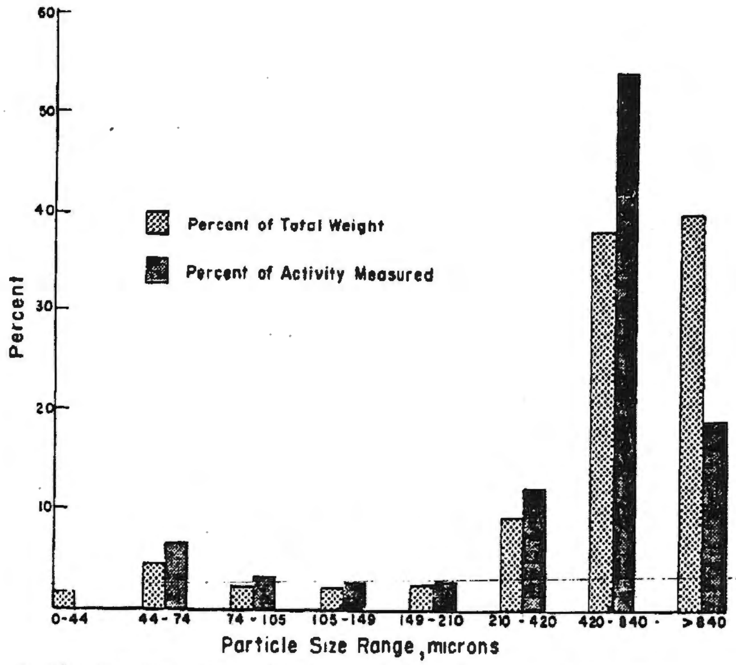

Figure 3.48 Weight and activity distribution for Bravo sample, Shot Zuni, 59,800 feet from ground zero.

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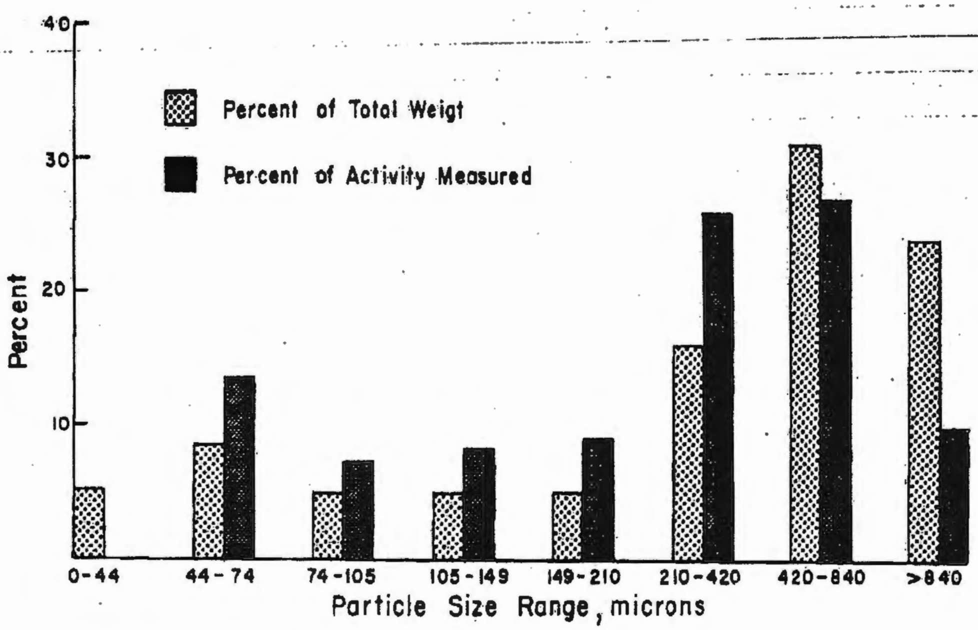

Figure 3.49 Weight and activity distribution for Charlie sample, Shot Zuni, 78,080 feet from ground zero.

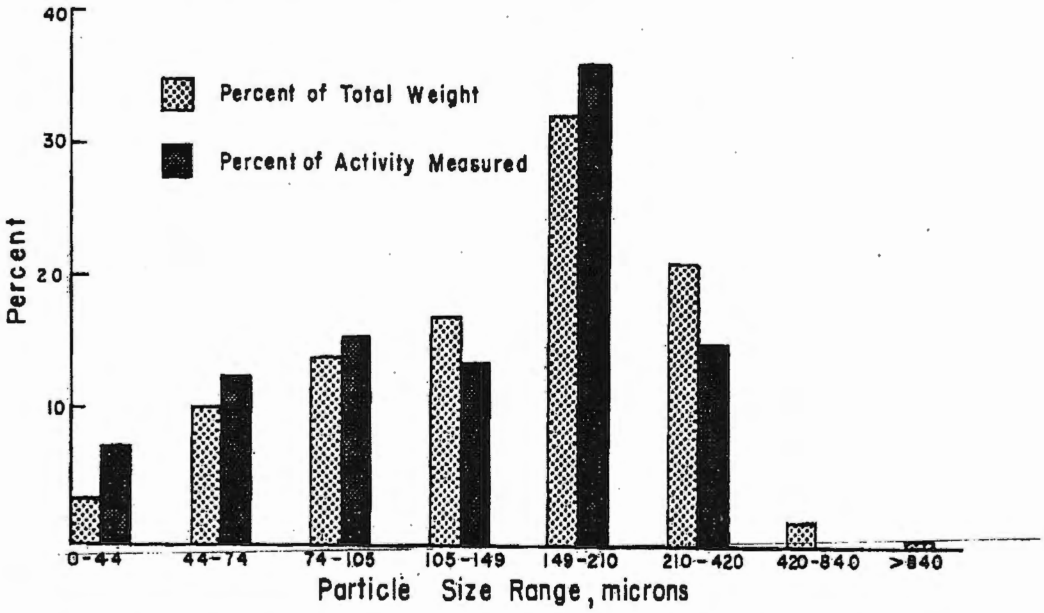

Figure 3.50 Weight and activity distribution for YAG-40 sample, Shot Zuni, approximately 50 miles from ground zero.

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Figure 3.51 The 210-to-420 μ particles from Gene canvas sample, Shot Lacrosse.

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CHAPTER 4

DISCUSSION

4.1 DECAY MEASUREMENTS

The field gamma dose rate decay curves shown in Figures 3.1 to 3.5 were constructed by fitting a straight line to three points by inspection. The curves can only be expected to give a good indication of the order of magnitude of the overall decay slope for the first 50 hours after detonation. The relatively close agreement between the slopes of these field dose rate curves and the early slopes of the laboratory gamma dose rate decay curves, as shown in Table 3.2, indicates that, for short time intervals, normal weathering has little effect on contamination levels on the islands of the Pacific Proving Ground. Although a reduction of the contamination levels by the action of winds or water should cause an apparent increase in the rate of decay, the average field decay slope for Flathead was actually less than the slopes read from the first few points of the laboratory gamma dose rate decay curve for Flathead. Although small contamination levels resulting from Zuni existed immediately prior to Flathead, correction for these "background" readings has no significant effect upon the overall decay slope due to Flathead contamination. The dose rate readings on the islands due to the 14-day-old Zuni contamination were of the order of 150 to 200 mr/hr. The levels existing at about 9 hours after Flathead were of the order of 10,000 to 20,000 mr/hr. When all post-Flathead readings are corrected for the Zuni contamination, the average resulting decay slope is increased from 1.0 to 1.02.

The extremely heavy rains which occurred on D+1 day after Navajo and which continued for many hours did reduce the contamination levels resulting from this shot, as shown in Table 3.7. Apparent gamma decay slopes, based upon the D-day and D+1 day readings only, vary from -1.5 to -2.7 for all island sites surveyed except Bravo, where the apparent slope based on these two points is -0.98. Most of the surface of Bravo is extremely rocky, when compared to Sites Able through How, which have a sandy surface.

The significance of the beta decay curves will be discussed in the final report after a complete analysis of all data has been made.

4.2 AERIAL SURVEY DATA

During Shots Lacrosse and Mohawk, emphasis was placed upon obtaining dose rate readings near the craters. The high readings obtained in the

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area immediately around the Lacrosse crater, as shown in Figure 3.18, were calculated from survey readings obtained on D+1 and D+2 days at low tide. These levels were observed in spite of the fact that the reef around the crater had been washed over by at least two high tides before the readings were taken. The actual H+1 hour values close to the crater may conceivably have been higher than those reported.

Abnormally high readings, similar to the one which gave an H+1 hour dose rate of 57,000 r/hr, were not observed for any other point. Observations made by a ground recovery party indicate that many fairly large, extremely radioactive, partially fused pieces of metal were scattered around the end of Yvonne toward the crater. On one occasion, at a location where the general background was on the order of 200 mr/hr, the meter reading very near one large piece of metal was on the order of 500 r/hr. The one abnormally high reading shown in the figure may have been due to the presence of such material at or near the point at which the probe support touched the ground. This reading, therefore, is not necessarily representative of the general dose rate reading near the crater lip.

The results of the survey of the area near the Mohawk crater show consistent H+1 hour dose rates of from 10,000 to 13,000 r/hr. These values are based upon readings taken over land areas which are not submerged by tides and represent higher contamination levels than have been observed on previous atomic weapon tests (Reference 2).

The aerial survey instrument provided a practical means of determining the dose rates at early times for specific points on the surface.

4.3 VARIATION OF GAMMA DOSE RATE WITH HEIGHT ABOVE SURFACE

An attempt to determine air-to-ground gamma dose rate conversion factors following Shot Lacrosse did not give meaningful results, because the requirements for a fairly uniform radiation field, a relatively high level of contamination, and a large surface area over which the measurements were to be taken were not satisfied. A suitable island, meeting all requirements, could not be found. Observations made on Yvonne showed instances where the readings in the helicopter were higher than the probe reading at the 3-foot level directly beneath. This situation can exist where exceptionally steep gradients occur in the contamination field on the surface. In such cases, attempts to convert readings at the helicopter position to readings at the surface are meaningless.

The air-to-ground conversion factors obtained for Shots Zuni and Flathead are based upon measurements made over the Cherokee target area on Site Charlie. The width of the island at this point is approximately 2,000 feet, and the surface dose rates were reasonably uniform. The Zuni and Flathead results are compared with those from Shot 7 of Operation TEAPOT (Reference 11) and with theoretical curves (Reference 19) in Figure 4.1. The lack of agreement between the Flathead and Zuni curves is most likely due to variation in the spectra of the contamination with time or with weapon.

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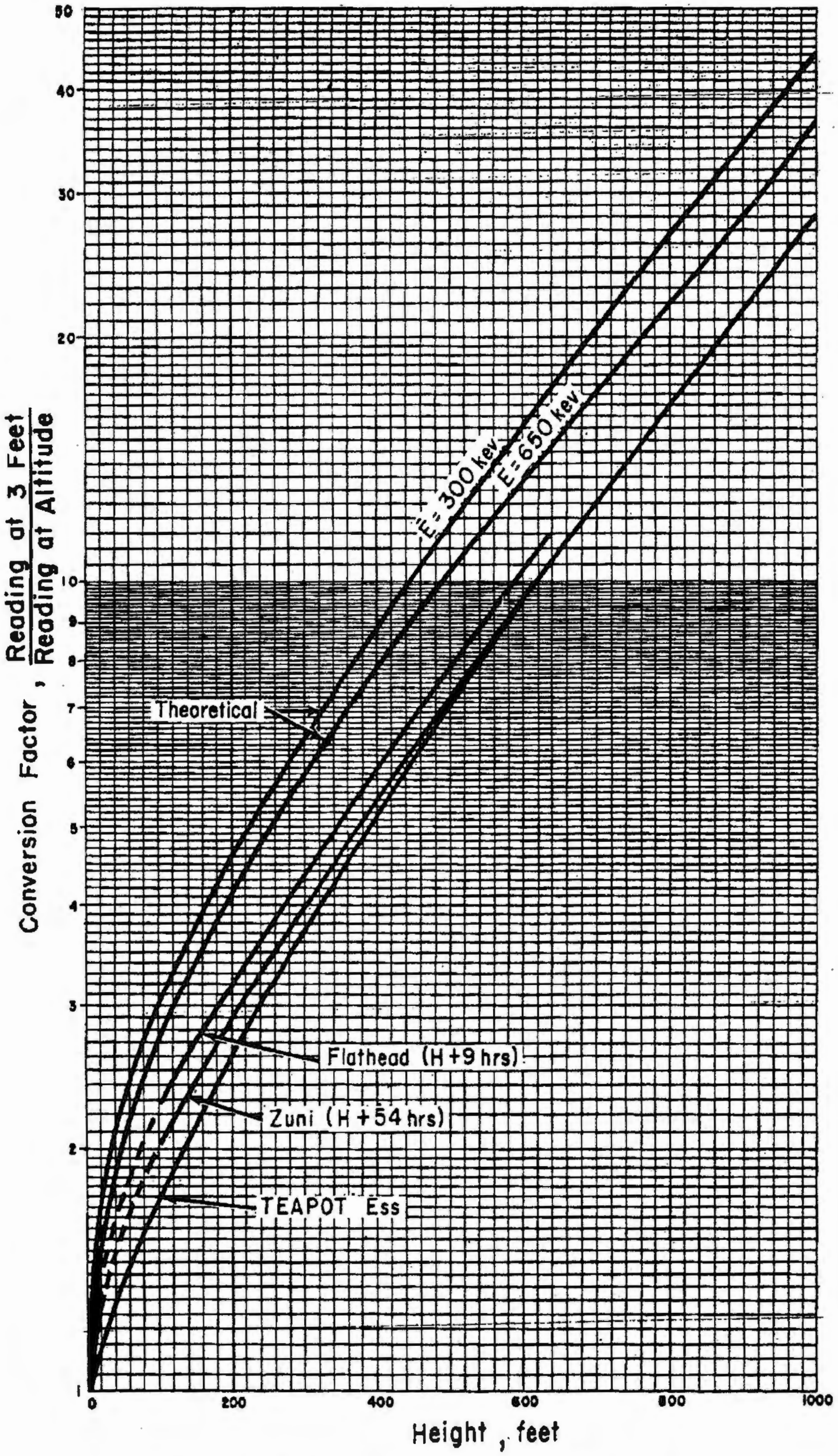

Figure 4.1 Gamma dose-rate conversion factors.

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4.4 TIME OF ARRIVAL, RATE, AND DURATION OF FALLOUT

The period during which significant fallout was collected and the time at which the maximum rate of fallout occurred are summarized in Table 4.1 for all shots in which time-incremental samples were collected. Also included in the table are the times at which the dose rate reached

TABLE 4.1 TIME OF ARRIVAL, RATE, AND DURATION OF SIGNIFICANT FALLOUT ACTIVITY

Shot	Station	Distance From Ground Zero	Interval During Which Fallout Occurred	Time of Maximum Rate of Fallout From IFC's	Time at Which Dose Rate was Maximum From Project 2.2
		ft		min	min
Zuni	Otoe	16,000	16 min to >22 min	19 to 20	
	William	35,000	15 min to 2.5 hr	25 to 30	
	Yoke	43,000	30 min to 1.5 hr	35 to 40	40
	Charlie	78,000	40 min to 3.5 hr	85 to 90	
Flathead	George	15,050	<30 min to >10 hr	90 to 120	80
	Charlie	36,780	<30 min to >10 hr	90 to 120	
Navajo	Charlie	37,790	30 min to 2 hr	45 to 50	
Tewa	George	31,690	30 min to 4.5 hr	150 to 180	
	YFNB-29	41,400	25 min to >110 min	50 to 75	
	Yoke	56,240	35 min to >110 min	65 to 70	
	William	59,400	30 min to 4.5 hr	150 to 180	

its maximum value, as determined by the Project 2.2 residual dose rate recorder.

4.5 WEIGHT AND ACTIVITY OF THE FALLOUT SAMPLES

The activity concentrations of the fallout from both Shots Lacrosse and Zuni were higher at the distant stations than at the relatively close-in stations. Table 3.11 shows that the activity per unit weight of the Zuni sample collected on the YAG-40 at a distance of approximately 50 miles was much larger than for samples collected within the area of the atoll. A comparison of the weight and activity distributions for the YAG-40 samples and the island samples shown in Figures 3.46 through 3.50 indicate that the distant samples had a much smaller percentage of particles in the larger size ranges.

The problems encountered in obtaining representative samples from the Flathead and Navajo barge shots and in recovering the active material from the collectors suggest that large fractions of the activity reached the surface as liquid droplets. Although some dry solid material was collected after each of these shots, the greater portion of the activity was associated with a wet slurry or was observed on collecting surfaces which, in some instances, showed small spots where liquid droplets had dried.

A comparison of the weight or particle-size distribution of the solid portion of the fallout with its activity or with the total activity collected is of doubtful value.

The data on the samples from the intermittent fallout collectors on Charlie and George during Shot Flathead are included in Table 3.10 for

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purposes of comparison only. The activity per unit area of collecting surface for the loose particles in these collectors is of the same order of magnitude as for the same type of particles in the gross fallout collectors.

The influence of the surface wind speed on the angle of incidence of small droplets or particles and the effectiveness of tilting the collecting surface so that it is approximately normal to the path of the fallout was established in the Navajo test. A semiquantitative comparison of the amounts of fallout activity collected in the tilted and horizontal collectors after the Navajo barge shot showed that several times as much activity was collected by the instrument which was tilted and turned into the wind as by the one which was left in the usual horizontal position. A more precise comparison will appear in the final report after all analyses have been completed. Although this procedure was effective in collecting wet fallout, which adheres to the surface of the point of impaction, larger dry particles may not be collected efficiently in this way. It should be pointed out that tilting a collecting surface so that it is turned into the surface wind is relatively simple at the Pacific Proving Grounds, where the surface wind direction remains fairly constant.

4.6 RADIOCHEMICAL AND INDIVIDUAL PARTICLE EXAMINATION

Since the coral particles in the fallout from Shots Lacrosse and Zuni were generally homogeneous mixtures of $CaCO_3$ and CaO or $Ca(OH)_2$ and looked similar to natural coral, they could not have resulted from vaporization in the fireball and subsequent condensation. (The CaO or $Ca(OH)_2$ can be explained by calcination at temperatures below the melting point). Nevertheless, most of these particles were radioactive throughout their volumes. The most plausible explanation for this result is that these particles were contaminated by contact with radioactive liquid. The feasibility of this process was tested by treatment of natural coral particles with Lacrosse liquid fallout, with the result that some of these particles became radioactive throughout. It is more difficult to ascertain whether this process occurred in the cloud or on the ground, but the dry appearance of the Gene canvas sample and the fact that the Charlie gross fallout collector collected no liquid suggest that the process probably occurred in the cloud.

The suspension of $CaCO_3$ in the Zuni YFNB-29 liquid sample (see Section 3.7.2) evidently resulted from the action of atmospheric CO_2 on $Ca(OH)_2$ in the solution. A similar effect was observed following the IVY Mike shot.

(b) (3)

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(b) (3)

Since the 210-to-420-micron size range (in which the activity of the black particles was measured) made up 87 percent of the Lacrosse fallout activity, 25 percent contribution of the black particles to the total activity can be considered to be approximately correct for the Lacrosse fallout, in general.

The spherical particles in the Zuni fallout were probably condensed from fireball material as CaO, and the subsequent action of moisture and atmospheric CO_2 produced the observed carbonate shell. Further action of CO_2 would account for the eventual disintegration of these particles.

It was pointed out in Section 3.6.2 that the fallout scooped from the deck of the YAG-40 was heavily agglomerated in the higher size ranges and that water broke up the agglomerates into a suspension of fine particles (50 microns or less) in a NaCl solution. The obvious conclusion is that the agglomeration was caused by salt spray.

It was anticipated that the significant fallout from water-surface shots would be liquid. It was therefore surprising to find little liquid in the Flathead samples. Instead, the overwhelming majority of the activity appeared in an aqueous slurry of NaCl crystals, Fe_2O_3 particles, and fine $CaCO_3$ particles. The Fe_2O_3 most likely came from the barge itself. The $CaCO_3$ probably resulted from the 200 tons of coral ballast on the barge. Although one would expect this material to result in CaO or $Ca(OH)_2$ particles, the particles found were small enough that they might have been readily converted to the carbonate. The NaCl, originating from sea water, may have been in solution when it fell out and crystallized because of evaporation. The large, discrete, $CaCO_3$ particles found in the intermittent collectors and in the apices of the gross collectors are more difficult to explain. The virtual absence of $Ca(OH)_2$ in these particles and their low activity obviate their having been incorporated in the fireball, as would have been the case with the ballast coral. A possible explanation may be that these particles originated from the floor of the lagoon, whence they were drawn up mechanically into the column of the cloud. The presence of more solid material in Shot Flathead than in the CASTLE barge shots, upon which the expectations were based, may be explained by the comparatively high yields of the latter, which would cause wider dispersion of barge material.

(b) (3)

(b) (3)

[redacted])however, since it has been shown in Section 3.5 that the intermittent collectors did not collect the most significant type of Flathead fallout material (viz, the brown mud), the IFC radiochemical results cannot be considered representative of the true fallout.

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CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The tentative conclusions presented in this report are based upon a preliminary evaluation of the data. They may be changed upon further analysis of the present data or upon the development of additional data at the laboratory.

Data from other projects will be required before conclusions can be drawn on Objectives 2 and 3.

5.1 CONCLUSIONS

1. The Cherokee air burst did not produce significant fallout in the Bikini Atoll.
2. The early field gamma-dose-rate decay for fallout-contaminated islands in the Pacific Proving Ground is not significantly affected by the usual conditions of wind and rain. However, extremely heavy rains lasting for several hours will, in the case of water-surface shots, increase the apparent rate of field gamma decay.
3. The aerial survey instrument used by this project provides a practical means of determining precise contamination levels at surface locations in high radiation fields.
4. The maximum radiation dose rates observed on the ground near the Lacrosse and Mohawk craters were higher than those reported after any previous nuclear detonation.
5. The activity per unit weight of fallout resulting from land-surface bursts is higher at distant stations than at relatively close-in stations.
6. For water-surface shots, fallout-sampling devices different from those used are required to collect meaningful samples.
7. Seventy-five percent of the Lacrosse fallout activity was contributed by partially calcined coral particles which became contaminated throughout by contact with radioactive liquid.
8. Twenty-five percent of the Lacrosse fallout activity was contributed by sintered, black particles which contained iron.

(b) (3)

[redacted]

(b) (3)

13. Almost all of the fallout activity from Shot Flathead was associated with a brown mud.

5.2 RECOMMENDATIONS

There are no recommendations at this time.

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APPENDIX A

EXPERIMENTAL EQUIPMENT

A.1 INTERMITTENT FALLOUT COLLECTOR

The intermittent fallout collector (IFC) is a modification of the collector used during Operations IVY, CASTLE, and TEAPOT (References 8, 9, and 11). It consists of a circular steel tub, 40 inches in diameter and 24 inches in height; a circular disc or spider, divided into 24 sectors; a driving and timing mechanism; and a power supply. Twenty-two triangular sampling trays, each 3 3/8 by 10 by 3/4 inches deep, are placed into the sectors. The first and last sector are left empty. One tray at a time is exposed to bass surge or fallout or both through an opening the size of the sampling tray in the top cover. A door covers the sampling opening both before the initial and after the final sampling time.

The instrument is started by an external timing signal. A self-contained interval clock timer controls a mechanism which moves the trays into sampling position. Succeeding trays move into position under the cover opening at set time intervals until the cycle is completed, after which the door closes and the machine shuts itself off. Two views of the intermittent fallout collector are shown in Figures A.1 and A.2.

A.2 GROSS-FALLOUT COLLECTOR

The gross-fallout collector is composed of a metal support framework and a conical liner with a door covering the opening. The liner has an opening approximately 2 feet in diameter at the top. In the bottom of the cone, which is 5 inches in diameter, is a stainless-steel filter. There is a small hose below this going to a polyethylene bottle. Figure A.3 shows the collector with the door open, and Figure A.4 shows the device with the door closed.

The door opens and closes with a sliding action. It has a notched strip rack on its top and is driven by a 24-volt direct-current motor through a chain-and-gear drive system. The sliding motion of the door is stopped when the door trips a microswitch at either the full-open or the full-closed position.

The control system consists of a power relay for the control circuitry, a power relay for the motor, a reversing relay for the armature, and a timing system composed of a direct-current motor and a preset register. The control system is actuated by the closing of a relay in an Edgerton, Germeshausen, and Grier, Inc. (EG&G) blue box at the time

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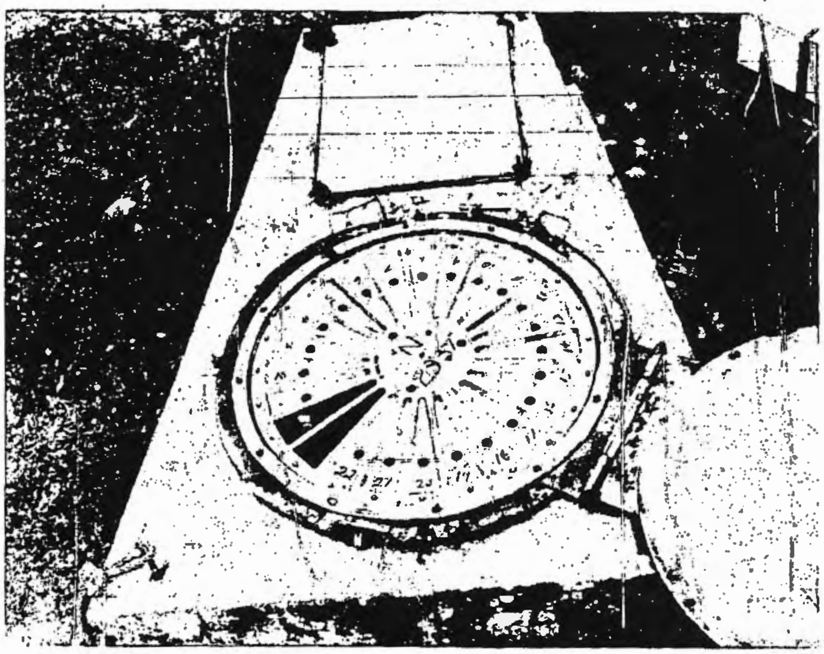

Figure A.1 Intermittent fallout collector with cover open, exposing collecting trays.

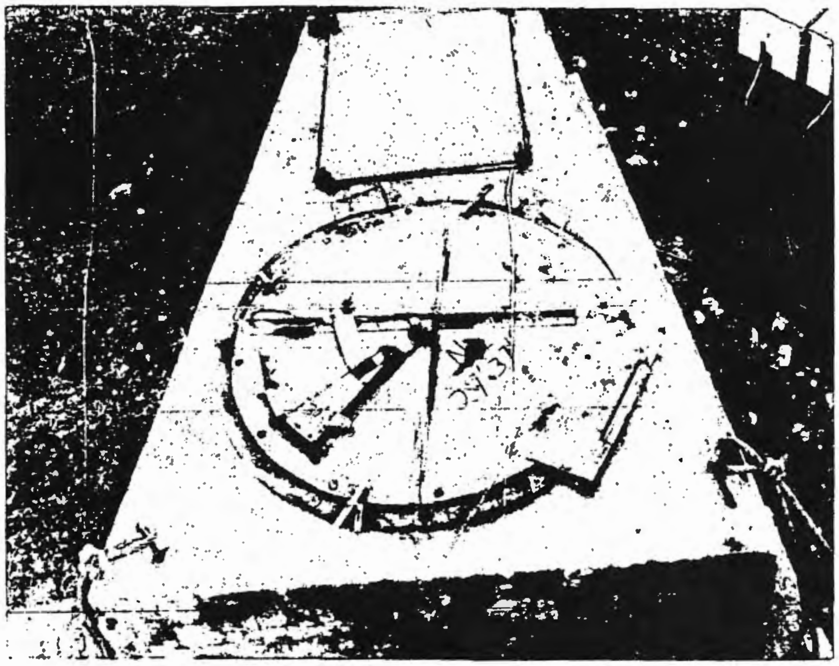

Figure A.2 Intermittent fallout collector with door closed.

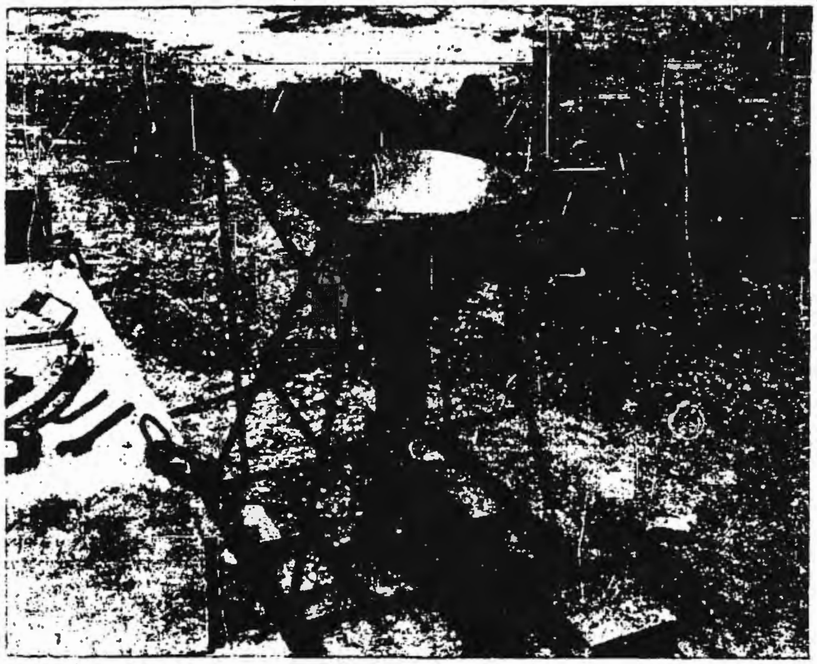

Figure A.3 Gross fallout collector with door open.

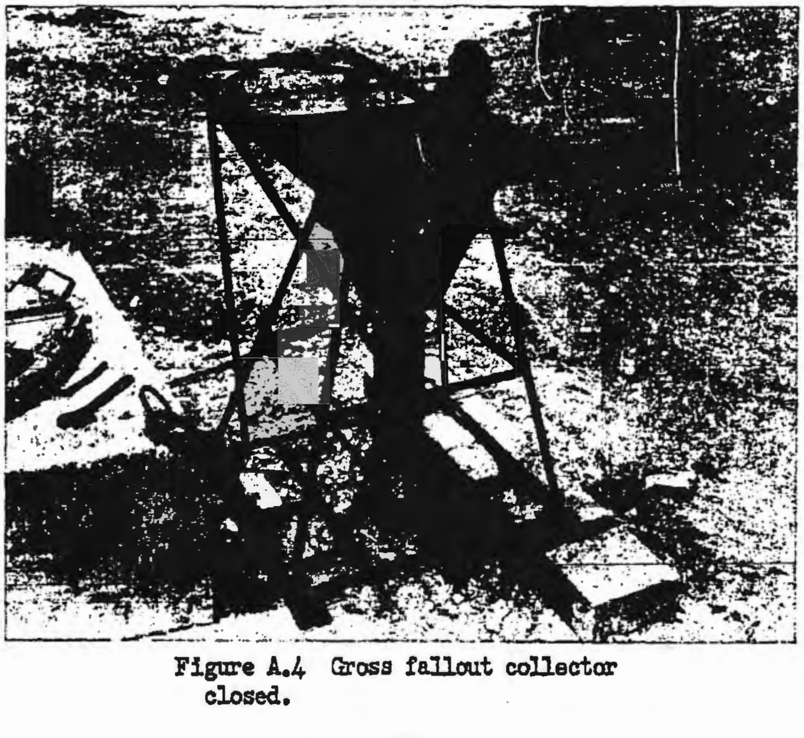

Figure A.4 Gross fallout collector closed.

of the detonation. The motor immediately opens the door until it closes the microswitch, which applies 24 volts to the motor field and, at the same time, shorts the armature. This stops the motor with less than 1/2 inch of sprocket travel. At the end of 11 hours, the timer actuates the circuit, and the reversing relay is de-energized. The motor then closes the door until it contacts the other microswitch.

During recovery, the door is opened manually, and a cover is put on the cone liner. After the hose is disconnected, the cone liner and the bottle are removed from the gross collector and transported to the laboratory area.

A.3 BASE-SURGE DETECTOR

The base-surge detector consists of a sealed-beam light, photovoltaic cell, timer, inverter, and batteries. The photovoltaic cell and the sealed-beam light source are placed 3 feet above the ground and 10 feet apart inside heavy brass holders which are mounted on 4-inch pipes embedded in concrete blocks at the ground surface (Figure A.5).

As soon as the timing signal is received, power is supplied from the batteries to the sealed-beam spotlight (6 volts), the ATR inverter (12 volts) and to the 1/30-rpm local timer (12 volts).

Light from the sealed-beam lamp is focused on a G. E. PV-10 photovoltaic cell located 10 feet away.

The ATR inverter supplies 110 volts of alternating current to a Brown electronic recorder. As soon as the power is turned on, the chart in the recorder starts. However, the electronic components require approximately 20 seconds warm up before proper functioning.

When the base surge arrives, light from the spotlight is attenuated, the signal from the PV-10 is reduced, and the recorder pen is deflected, indicating the time of arrival of the base surge at the station.

The 1/30-rpm timer disconnects the equipment at the end of 30 minutes.

A.4 TAPE FALLOUT MONITOR

The tape fallout monitor is an intermittent fallout collector using adhesive tape for the sampling surface. The sampling surfaces are changed by pulling the tape through the collector with a 24-volt direct-circuit motor. The tape feeds from its supply reel over a roller, under the sampling port in the cover, over another roller, and onto the power-driven take-up reel. There is another supply reel which contains a roll of Saranwrap. The Saranwrap covers the surface of the tape after the fallout has collected. The instrument is tilted slightly, so that water will drain off the tape. The water is collected in a polyethylene bottle.

The control circuitry consists of a power relay, two timers, two switching relays, and a register with the shutoff switch. Also in the collector is a microswitch operated by a screw on the side of the first roller. The circuit is actuated by the closing switch in an EG&G blue box at the time of detonation. The motor is energized until the tape has turned the first roller far enough to close the microswitch. This switch disconnects the power from the motor. The switches in the timers reactivate the motor relay each time they close. The first timer closes its switch every 2 minutes, thereby taking 30 samples the first hour. Then the second timer disconnects the first timer, changing the sampling times to an hour each, and the instrument continues to operate for a total of 48 hours. There is a solenoid in the instrument which operates a ball-point pen on the tape so that each sampling area is marked.

The entire instrument is recovered from the field and the bottle and tape are removed for counting.

A.5 DISTANT FALLOUT STATION

The distant fallout station consists of a total fallout collector, two dust samplers and a tape fallout monitor.

The total fallout collector is a wooden box, 4 feet square, covered by a manually operated sliding door. The inside of the box is lined with cloth covered by aluminum foil. This liner collects the sample and is changed each time the box is used.

The dust samplers are motor-driven blowers which draw the air and dust in the air through filter paper.

The tape monitor is essentially the same as previously described, except that it is modified to collect hourly samples only.

The equipment is manually switched on and the box opens when activity starts to fall. It operates for a period of 24 hours, at which time the box is manually closed and the equipment switched off.

A.6 AERIAL SURVEY EQUIPMENT

The aerial survey equipment consists of a radiation detector mounted in a probe which can be lowered from a helicopter by means of a special cable and a powered reel. Figure A.6 shows the probe, tripod, meter, and control panel and Figure A.7, the control panel and winding mechanism installed in an H-19 helicopter. The detector is wired through the special cable (four conductor, 1/8-inch outside diameter) to a meter and control panel inside the helicopter. A maximum of 2,000 feet of cable is carried on the reel, enabling the helicopter to hover in the air, lower the probe to the ground, and obtain direct ground readings without exposing personnel to the full intensity of the ground radiation.

Each direct ground reading is taken with the detector mounted in a probe with a tripod frame. The probe is designed to protect the detector chamber from mechanical abuse, and the tripod (which is collapsible to facilitate handling and storage) holds the detector 3 feet above the ground while the readings are being taken.

The radiation detector is a survey meter, Jordan Model AGB-10K-SR, modified for use with the special cable and reel system. This meter uses a metal-shelled ionization chamber of the Neher-White type. Sealed inside is a subminiature tube in 10 atmospheres of pure argon. A relatively high-output current from the chamber flows directly to the indicating meter, eliminating the need for complex circuitry. The response is logarithmic, which makes possible the wide range of 0.01 mr/hr to 10,000 r/hr

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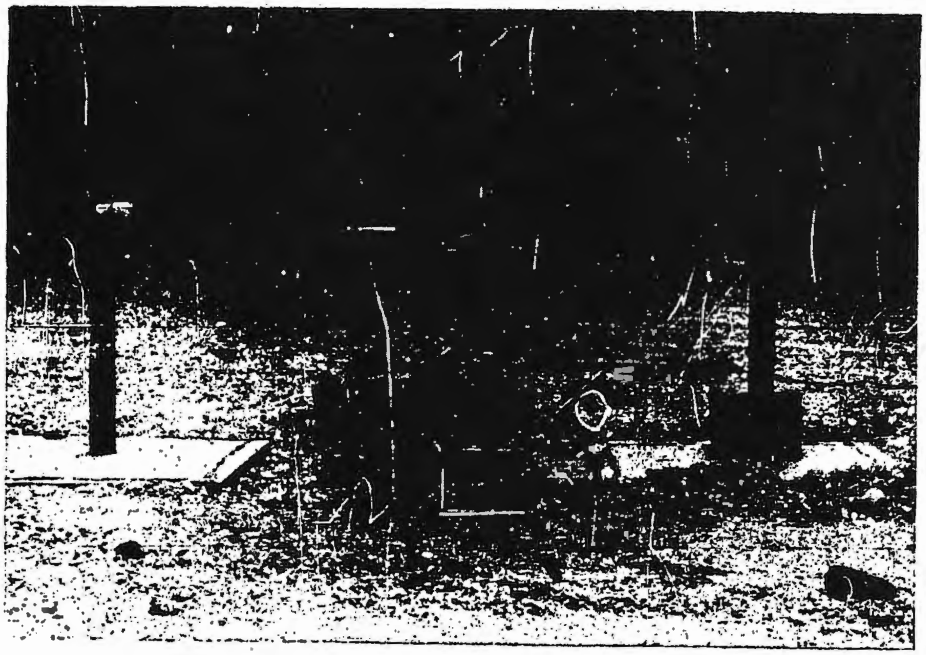

Figure A.5 Project 2.65 base-surge station on Oboe.

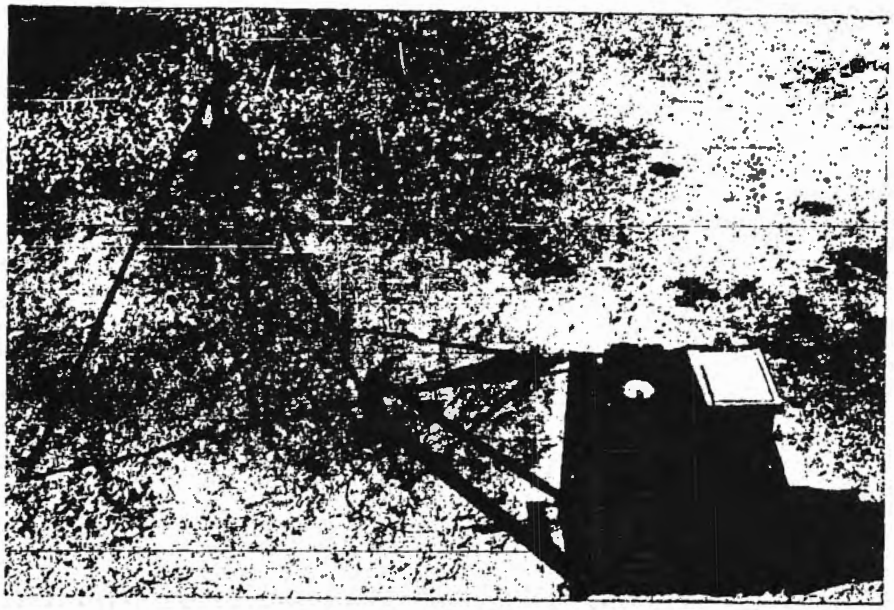

Figure A.6 Tripod with probe and control panel of aerial survey instrument.

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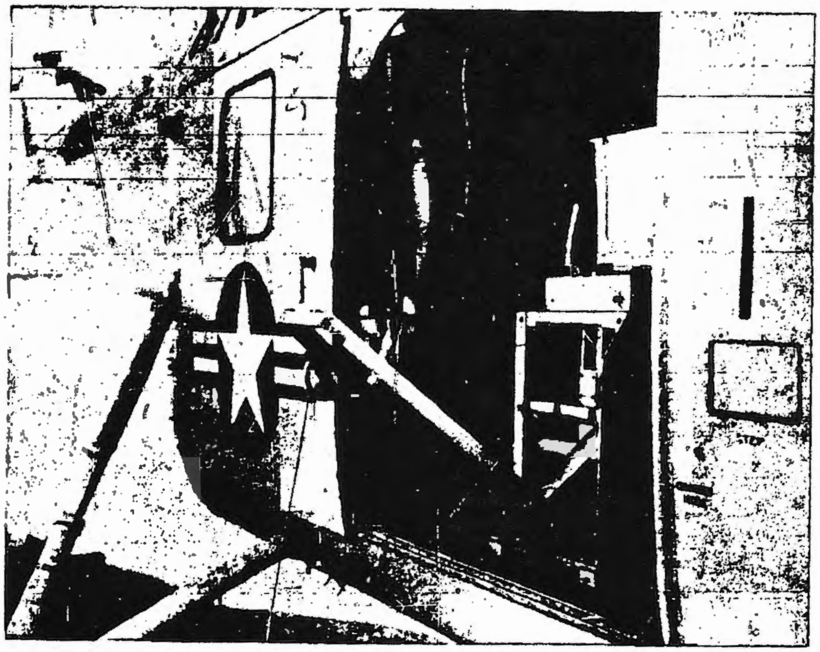

Figure A.7 Aerial survey instrument installed in helicopter.

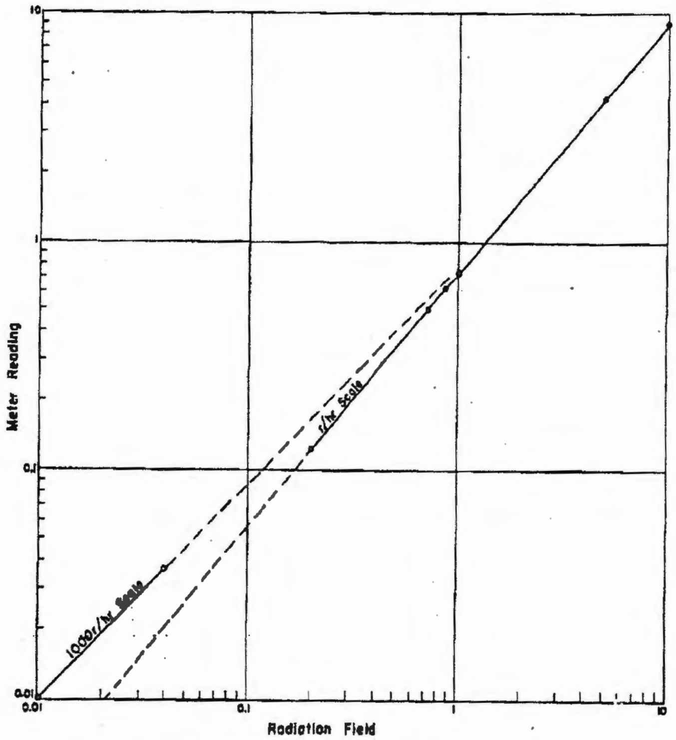

Figure A.8 Lacrosse calibration curve for aerial survey meter.

in three scales. Accuracy is quoted at ± 10 percent of applied dose rate anywhere on scale. The spectral response of the instrument is made essentially flat between 75 kev and 1.3 Mev by the use of a lead absorber on the outside of the steel chamber shell and an aluminum secondary emitter on the inside.

The reel, mounted in an aluminum frame, is operated by a 24-volt direct-current motor powered by the helicopter's electrical system. The motor is reversible, and its speed-control system incorporates dynamic braking, enabling the reel operator to lift or lower the probe at any speed up to 500 feet per minute. There is an emergency brake on the reel and a level-wind mechanism to prevent the cable from fouling. A counter is used to indicate the length of cable reeled out.

The aerial survey instrument is designed as a portable unit, weighing approximately 150 pounds. Installation in the helicopter involves strapping the unit to the floor and making a connection to the helicopter's electrical system.

In addition to the helicopter pilots, a crew of two is required to operate the aerial survey instrument and monitor the helicopter. A separate survey meter, Jordan Model AGB-10K-SR, is used to monitor the inside of the helicopter during each mission.

In use, the probe is lowered through the side door of the H-19 helicopter as it hovers above a checkpoint on the ground. When the tripod is on the ground, a reading is taken, the operator then reels in sufficient cable to clear obstructions, and the helicopter moves to the next checkpoint, where the procedure is repeated.

Another use of the aerial-survey instrument is to study air attenuation of the gamma radiation from fallout material on the ground. Data is obtained by the raising of the probe and taking of readings at various altitudes above an initial point on the ground. For this work the instrument is equipped with a counter indicating the number of feet of cable suspended from the helicopter and an altimeter accurate to ± 10 feet.

A.7 AERIAL SURVEY METER CALIBRATION PROCEDURES

Throughout Operation REDWING, the aerial survey meter (ASM) was calibrated against a known source of Co^{60}. Co^{60} was chosen because of its availability and because its gamma energy levels (1.17 Mev and 1.33 Mev) fall within the flat-response region of the Jordan instrument. (The response of the Jordan ionization chamber is essentially independent of the energy of the gamma radiation from 80 kev to 1.3 Mev. The response drops off sharply below 70 kev.)

Arrangements were made to use the Project 2.1 collimated source of Co^{60} on Site Elmer. This source gave checkpoints from 100 mr/hr to 50 r/hr. All except a few of the ASM readings fall within this range.

For Mohawk, where very high readings were expected, an additional calibration was made against the Project 2.1 2π source of Co^{60}, which gave checkpoints from 50 r/hr to 5,000 r/hr. This source was not available when the high readings were taken on the Lacrosse crater survey.

The calibration procedure for Lacrosse and Zuni was to adjust the instrument following the standard calibration procedure described in the Jordan literature, placing an open beta window over the built-in Sr^{90}

source. After the instrument was adjusted, the beta window was closed and a calibration curve was run against the collimated Co^{60} source by the placing of the chamber in known dose rates and plotting meter readings versus known dose rates. This curve was then used to correct subsequent survey readings. The advantage of this procedure was that a calibration could be obtained in the field by using the built-in Sr^{90} source. However, this procedure was found unsatisfactory and was not used after Zuni, because the intensity of the built-in Sr^{90} source is so low that even a slight amount of contamination on the chamber rendered the source useless for calibration purposes. Likewise, a high background, such as the level on Site Nan after Shot Zuni, had the same effect.

After Zuni, the calibration procedure did not make use of the built-in Sr^{90} source. Instead, the instrument was adjusted by the use of known intensities on the collimated Co^{60} source. The chamber was then placed in known dose rates from 100 mr/hr to 50 r/hr and a calibration curve drawn up of meter readings versus radiation field. A typical curve is shown in Figure A.8.

This calibration procedure was followed before each shot, and the calibration curve was used to correct all survey readings for the shot. No instrument adjustments were touched during this time. After these surveys were made, another calibration curve was run before any instrument adjustments were made. The calibration curves run before and after the shots showed no appreciable deviation, thus assuring the accuracy of the corrected survey readings.

Stability tests were made on the ASM, and it was determined that there was no appreciable drift when the instrument was used intermittently over a 2-week period. These tests also showed that a 10-minute warm-up period was sufficient and that there was no appreciable drift when the meter was left on continuously for a period of 2 hours, the approximate time of an atoll survey.

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APPENDIX B

ANALYTICAL PROCEDURES

B.1 ANALYSIS OF BETA ACTIVITY PER UNIT WEIGHT

Beta activities were determined by placing weighed portions of the samples in stainless-steel counting cups and counting with Tracerlab G-M tubes having window thicknesses of less than 2 mg/cm . The tubes were mounted in vertical lead shields, Technical Associates Model AL 14A, having a wall thickness of 2 inches of lead, 0.25 inches of brass, and 0.25 inches of aluminum. A geometry-defining brass plate was inserted between the G-M tube and the sample (Reference 20). The output of the tubes was fed into scalers, Atomic Instrument Company Model 1060, having a characteristic resolving time of 5 μsec.

The samples were counted for activity in the following manner: Samples with activities greater than 1,000 counts/min were counted for 10,000 total counts; samples with activities less than 1,000 counts/min were counted for 10 minutes. Each sample was counted twice; in cases where the two counts did not agree within one standard deviation, a third count was taken and the three counts averaged.

It was necessary to apply several corrections in order to approximate the actual disintegration rate of the samples. The method most commonly used to obtain disintegration rate of a sample is to compare the sample under consideration with a known source, counted in an identical manner. However, there is no one known source which represents fission products containing many different isotopes. The procedure used here evaluated the various correction factors in terms of the sample itself and, thus, avoided the errors associated with a direct comparison with a single isotope standard. The procedure is outlined as follows:

1. The readings were corrected for coincidence loss (Reference 21).
2. The counts were corrected for geometry, G_p, defined as the percent of solid angle subtended by the sensitive volume of the G-M tube, by a factor obtained using the first three terms of the Blachman series (Reference 22). Succeeding terms of this series are insignificant and were not used in this correction.
3. Back-scattering determination, f_b, was made by placing small amounts of the samples under consideration on rubber hydrochloride mounts and counting them with this arrangement, which almost completely eliminated scattering. The same sample then had a stainless-steel bottom placed under it and a stainless-steel ring, to simulate the sides of a cup, placed around it. It was again counted in this arrangement, and the

[redacted] - [redacted]

following factor was obtained:

$$f_b = \frac{\text{count of sample on film}}{\text{count of sample in simulated cup}} \qquad (B.1)$$

Such determinations are dependent on time and, therefore, apply only at the time of determination. For this reason, this correction factor was obtained at the approximate time the samples were counted.

4. A correction was made for absorption by the air between the sample and the tube window and by the tube window itself (Reference 23). To obtain this correction, precise mica-absorption curves were run on samples from each shot. A correction factor, f_w, was calculated from the equation:

$$f_w = \frac{n_t}{N_o} = e^{-ut} \qquad (B.2)$$

Where: t = The thickness of material between source and sensitive volume expressed in mg/cm^2.
n_t = Corrected counting rate observed with thickness t between the source and sensitive volume.
N_o = True beta counting rate at zero thickness.
u = The mass absorption coefficient in cm^2/mg.
$= \frac{1}{t} \ln \frac{n_t}{n_{t+\Delta t}}$

Where: $n_{t+\Delta t}$ = Counting rate at thickness $t + \Delta t$.

This method assumes that the effective range distribution of the beta particles extrapolated to zero range is an exponential having the same slope when plotted on semilog paper as the slope of the measured portion of the absorption curve.

5. Self-absorption and self-scattering corrections for the samples in question were considered negligible, since the weight per unit area was kept to less than 10 mg/cm^2.

According to Coryell and Sugarman, for a radioactive beta sample with a weight per unit area between 5 and 10 mg/cm^2 and in which the maximum energy of all individual emitters are greater than 0.4 Mev, the self-absorption self-scattering correction is negligible (Reference 24). Furthermore, according to Hunter and Ballou (Reference 25) the nuclides with maximum energies below this value that contribute more than 1 percent of the gross fission activity constitute approximately 10 percent of the activity of the sample at the time the measurements for this report were made, i.e., approximately at H+100 hours. Therefore, the error entailed by the assumption of a negligible correction should be 10 percent or less. The practice of ignoring this correction has been further justified by comparison of the defined geometry method with 4π counting techniques.

6. The average sample beta activity A_b was treated by the above

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corrections to obtain the sample activity A_d in disintegrations per minute.

$$A_d \ (\text{dis/min}) = \frac{A_b \ (\text{counts/min})}{G_p \, f_b \, f_w} \qquad \text{(B.3)}$$

This method has been shown to give an accuracy within 10 percent with a mixture of radionuclides (Reference 26).

This activity in disintegrations per minute was then divided by the weight of the sample to achieve the final result in disintegrations per minute per gram at time of counting.

B.2 RADIOCHEMISTRY

B.2.1 Sample Preparation. The solid fallout samples designated for radiochemical analyses were dried at 110°C for 30 minutes and accurately weighed to ± 0.1 mg before dissolution. Accurate volumes of the liquid fallout or suspensions were taken for analysis after care was exercised in getting a homogeneous mixture. All fallout samples were treated with 5 to 10 ml of 6M HCl. If any material failed to dissolve, it was filtered, washed, transferred to an Erlenmeyer flask, and evaporated to dryness three times with aqua regia. It was then taken up in 5 ml of 6M HCl. Any material still undissolved was filtered, washed, and discarded. All the clear solutions were combined and diluted to an appropriate volume with distilled water.

The filter papers from the aircraft sampling of the cloud were cut into small pieces and digested with 10 ml of fuming HNO_3 for 30 minutes; 10 ml of concentrated HCl were carefully added, and the digestion continued for another 30 minutes; 2 ml of 70 percent perchloric acid were added, and the digestion was continued for a final 30 minutes. The clear solution was then evaporated to dryness, taken up in 6M HCl, and diluted to appropriate volume with distilled water.

B.2.2 Radiochemical Separation and Counting. The details of the separation procedures are given in Section B.2.3. Generally, four aliquots were taken for each analysis, and the average of the four was reported. In the analyses for Sr^{89}, Mo^{99}, I^{131}, Ba^{140}, and Ce^{144}, the final precipitates were mounted in the centers of 3¼-by-2½-by-1/16-inch aluminum plates. The Ce^{144} precipitate was evenly spread in a 1/32-inch depression 5/16 inch in diameter in the center of the aluminum plate. In the other analyses, the final precipitates were filtered through 7/8-inch-diameter filter papers, which were mounted in the center of the plates after they had been weighed and the chemical yields of the separations determined. A film of rubber hydrochloride (0.45 mg/cm²) was placed over the samples to eliminate any rearrangement of the precipitate. In the Np^{239} analyses, the final extractions were evaporated to dryness in small aluminum planchets 15/16 inch in inside diameter and 1/4 inch high. Special aluminum plates were fabricated with recessions in their centers to accommodate the small planchets.

[redacted]

All beta counting was done with thin end window GM tubes mounted in lead pigs, Technical Associates Model AL 14A. Sealers, Atomic Instrument Company Model 1060, were used to record counts. The GM tubes were supported by the usual lucite stages, in which the distances between the tube window and the absorber shelf, Shelf 1, Shelf 2, and Shelf 3, are 0.8 cm, 1.5 cm, 3.1 cm, and 4.7 cm, respectively.

Each sample was counted for a total of 10,000 counts or for a total counting time of 10 minutes. The former accounts for a 95-percent probability of being within 2 percent of the actual counting rate. The 10-minute time limit was expedient because of the large volume of counting that had to be done. All samples were counted through at least one half life, except for the SR^{89} and Ce^{144}. The samples on the aluminum cards have only two possible orientations in the counting system, 180 degrees apart; the averages of the two orientations were used. No special orientations for the planchets were maintained.

The individual nuclide activities were corrected (for radioactive decay) to zero time, for chemical yield, and for self-absorption and self-scattering. Each tube was calibrated for correction of counting rates to disintegration rates by actual measurement of a standard [redacted] for each nuclide analyzed.

(b) (3)

The alpha counter employed was an internal-sample, methane-flow counter operated in the proportional region. The ionizing gas was changed to a mixture of argon and methane about half way through the operation. A linear amplifier and an multiscaler, Atomic Instrument Company Model 1060, were used in conjunction with the flow counter. The discriminator in the scaler was set to eliminate all pulses but those due to alpha particles.

(b) (3)

The gross beta activities were measured on small aliquots of dissolved samples evaporated to dryness in glass planchets or cups. A film of rubber hydrochloride was glued over the tops of the planchets to prevent the absorption of moisture. In most cases the amount of material was small enough to eliminate significant self-absorption-self-scattering corrections.

B.2.3 Radiochemical Separation Procedures. The separation procedure for Ba^{140} and Sr^{89} is essentially that of Glendenin (Reference 27). The only significant modification is that the barium is finally precipitated and mounted as the chromate. The procedure consists of the precipitation of barium and strontium as the nitrates using fuming HNO_3. The nitrates are dissolved and scavenged with $Fe(OH)_3$. The final separation of barium from strontium is made by the precipitation of barium as the chromate, followed by the precipitation of strontium as the oxalate.

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The cerium procedure was developed by Glendenin and others (Reference 28). The substitution of ammonium oxalate for oxalic acid as the precipitating agent was the only modification. The cerium analysis involves the oxidation of Ce^{+++} to Ce^{++++}, followed by the extraction of Ce^{++++} from a 10 M HNO_3 solution with methyl isobutyl ketone. The Ce^{++++} is then reduced to Ce^{+++} and back-extracted into water. After adjustment of the pH, the cerium is precipitated as the oxalate, ignited to CeO_2, weighed, and mounted.

(b) (3)

As a modification of the original procedure, the final 8 N HNO_3 acid extraction is evaporated to dryness in a 40-ml conical centrifuge tube, taken up in 1 ml of H_2O with 3 drops of 30-percent H_2O_2, and evaporated to dryness in an aluminum planchet. The H_2O-H_2O_2 wash of the centrifuge tube is repeated once.

(b) (3)

The determination of Y^{90} was performed as an estimation of Sr^{90} concentrations. If a strontium separation is performed several days after fission, Sr^{89} and Sr^{90} will be isolated. Thirty days after the strontium separation, Y^{90} will have grown back into secular equilibrium with Sr^{90}. Consequently, yttrium analysis of separated strontium samples permits an

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estimation of the Sr^{90} concentration.

The procedure for yttrium by Stanley (Reference 32) was followed with one change in which petroleum ether was substituted for Gulf Solvent BT. The procedure involves the extraction of the nitrate from concentrated HNO_3 solution with tributyl phosphate diluted with petroleum ether. The yttrium is back-extracted into water, precipitated as the oxalate, and ignited to Y_2O_2.

The I^{131} procedure of Glendenin and Metcalf (Reference 33) was followed for analysis of this nuclide. The analysis calls for the oxidation of the I^- with NaOCl, followed by an extraction with CCl_4. The iodide is then reduced with 1M $NaHSO_3$ and back-extracted into water. After addition of 6M HNO_3 and 1M $NaNO_2$, the I_2 is extracted from the water with CCl_4. Finally, the iodine-CCl_4 layer is again treated with $NaHSO_3$ and extracted with water from which the iodine is then precipitated as AgI.

B.3 PROCEDURE FOR DENSITY MEASUREMENTS

The pycnometer procedure was used for the measurements of fallout density (Reference 34). The density of the fallout, D, was computed from the equation

$$D = \frac{ds}{s + p + Vd - w} \qquad \text{(B.4)}$$

Where: d = Density of pycnometer liquid.
s = Weight of fallout sample.
p = Weight of dry, empty pycnometer.
V = Internal volume of pycnometer.
w = Total weight of pycnometer, fallout sample, and liquid necessary to fill the pycnometer.

Toluene was used as the pycnometer liquid, and a value of 0.861 g/cm^3 was determined as its density at 25.5°C. The measurements were made in an airconditioned laboratory trailer; no additional precautions were taken to maintain constant temperature. The pycnometer, fallout sample, and toluene were kept under reduced pressure with occasional swirling for 1 hour to facilitate the removal of air from the sample.

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145 Assistant Chief of Staff, Installations, Headquarters, USAF, Washington 25, D.C. ATTN: AFCIE-E
146 Commander, Air Research and Development Command, PO Box 1395, Baltimore, Md. ATTN: RDDN
147 Commander, Air Proving Ground Command, Eglin AFB, Fla. ATTN: Adj./Tech. Report Branch
148-149 Director, Air University Library, Maxwell AFB, Ala.
150-157 Commander, Flying Training Air Force, Waco, Tex. ATTN: Director of Observer Training
158 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 2GTS, DCS/O
159-160 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
161-163 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOSI
164-165 Commander, Air Force Cambridge Research Center, LG Hanscom Field, Bedford, Mass. ATTN: CRQST-2
166-168 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
169-170 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Armament Training
171 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
172-173 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
174 Commander, Second Air Force, Barksdale AFB, Louisiana. ATTN: Operations Analysis Office
175 Commander, Eighth Air Force, Westover AFB, Mass. ATTN: Operations Analysis Office
176 Commander, Fifteenth Air Force, March AFB, Calif. ATTN: Operations Analysis Office
177 Commander, Western Development Div. (ARDC), PO Box 262, Inglewood, Calif. ATTN: WDSIT, Mr. R. G. Weitz
178-184 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

185 Asst. Secretary of Defense, Research and Development, D/D, Washington 25, D.C. ATTN: Tech. Library
186 U.S. Documents Officer, Office of the U.S. National Military Representative, SHAPE, APO 55, New York, N.Y.
187 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
188 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
189-194 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex.
195-196 Commander, Field Command, Armed Forces, Special Weapons Project, PO Box 5100, Albuquerque, N. Mex. ATTN: Technical Training Group
197-201 Chief, Armed Forces Special Weapons Project, Washington 25, D.C. ATTN: Documents Library Branch
202-208 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

ATOMIC ENERGY COMMISSION ACTIVITIES

209-211 U.S. Atomic Energy Commission, Classified Technical Library, 1901 Constitution Ave., Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
212-213 Los Alamos Scientific Laboratory, Report Library, PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
214-218 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Martin Lucero
219-221 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Margaret Edlund
222 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.
223-264 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

ADDITIONAL DISTRIBUTION

265 Commander, 1352 Motion Picture Squadron, Lookout Mountain Laboratory, 8935 Wonderland Ave., Los Angeles 46, Calif.

AEC, Oak Ridge, Tenn.

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